THE CONTENTS OF THIS SECTION ARE
THE HIGHEST QUALITY AVAILABLE

INITIAL gj DATE 9/27/02

PAGE NUMBERING SEQUENCE IS INCONSISTENT

Appendix F

Side Slope Armor Design

Side Slope Armor Design

PURPOSE: Determine sizing, gradation, and thickness for riprap and associated filter layers to be used on the perimeter slopes of the final cover of the landfill.

METHODOLOGY: Perimeter slopes are designed at 2.5 horizontal:1 vertical. Riprap sufficient to withstand erosional forces along these slopes was designed using the methods used by the Nuclear Regulatory Commission (NRC) for use at uranium mines. The method uses Stephenson's equation to calculate the median stone size (D_{50}) for the riprap.

$$D_{50} = \left[\frac{q\, K \left(\tan\theta\right)^{7/6} \eta_p^{\,1/6}}{C\,(32.2)^{1/2} \left[\left(1-\eta_p\right)\left(G_s - 1\right)\cos\theta \left(\tan\phi - \tan\theta\right)\right]^{5/3}} \right]^{2/3}$$

Where:
D_{50} = median stone size (ft)
q = Maximum flow rate per unit width
θ = slope angle measured from the horizon
η_p = rock fill porosity
C = empirical factor ranging from 0.22 for gravel and pebbles to 0.27 for crushed granite
g = acceleration of gravity
G_s = relative density of the rock
Φ = rock angle of repose
K = Olivier's constant

The maximum flow rate was determined using the Rational method. This method estimates the flow rate based on a runoff coefficient, the rainfall intensity and the drainage area. The runoff coefficient is estimated based on land use and soil type from the attached table 2.27. The drainage area is based of a unit width for the length of the drainage path. The rainfall intensity was determined using the Kirpich method. The Kirpich method determines a time of concentration, t_c. The time of concentration represents the time required for a drop of water to travel the length of flow. The value is calculated based on the length and slope of the flow path using the equation given below.

$t_c = 0.0078\, L^{0.77}(L/H)^{0.385}$

Where:
L = maximum length of flow in feet
H = difference in elevation in feet between the outlet of the watershed and the hydraulically most remote point of the watershed

The rainfall intensity is calculated from the t_c based on the probable maximum precipitation (PMP). The amount of the PMP precipitation to fall during the time t_c is the rainfall intensity. This number value is converted into inches/hour for use in the rational method.

The gradation for the riprap is determined based on the weight of stones starting with the W_{50} associated with the D_{50} value. The W_{15} and W_{100} sizes are determined using the following four rules.

1) $W_{100\ min} \geq W_{50\ min}$

2) $W_{100\ max} < 5 \times W_{50\ min}$

3) $16 \times W_{15\ min} \geq W_{100\ max}$

4) $W_{15\ max} < W_{50\ max}$

The minimum thickness of the riprap layer is twice the D_{50} size.

The filter layers were designed using the guidance from the NRC published in NUREG/CR-4620. The NRC procedure is based on two criteria:

1) $\frac{D_{15}(Filter)}{D_{85}(Base)} < 5$

2) $\frac{D_{15}(Filter)}{D_{85}(Base)} < 10$

The filter material is the coarser of the two material. The base material is the finer of the two materials being compared. The filter layers were developed using materials already in use in the cover system. Layers were designed to prevent migration of the water storage layer soils into the riprap. The minimum layer thickness for each filter layer is half the thickness of the riprap layer but not less than 9 inches.

Riprap Sizing and Gradation for Perimeter Slopes

OBJECTIVE: Determine the rip rap sizing, gradation, and thickness for rip rap that will be placed on the landfill perimeter slopes.

METHOD: The method outlined in Design of Erosion Protection for Long-Term Stabilization (NUCREG/CR-1623). This is attached to the calculation brief.

Kirpich Method

$t_c = 0.0078\ L^{0.77}(L/H)^{0.385}$

L = maximum length of flow in feet

H = difference in elevation in feet between the outlet of the watershed and the hydraulically most remote point of the watershed

Time of Concentration for top slope

Highest Elevation of the Landfill =	4974 ft
Lowest Elevation of the Landfill =	4948 ft
L =	435 ft
H =	26 ft
t_c =	2.482 minutes

Time of Concentration for side slope

Highest Elevation of the Landfill =	4948 ft
Lowest Elevation of the Landfill =	4920 ft
L =	76 ft
H =	28 ft
t_c =	0.322 minutes

Total t_c = 2.803 minutes

1 hour PMP Rainfall: 9.0 inch (from Hydrometeorological Report No. 57, see attached PMP map)

Rainfall Duration Minutes	% of 1 hr PMP
2.5	27.5
5	45.0
10	62.0
15	74.0
20	82.0
30	89.0
45	95.0
60	100.0

Interpolation

t_c for the cover is in between 2.5 and 5 minutes

D rainfall duration:	2.5	minutes
D PMP %:	17.5	%
D t_c and rain duration:	0.303	minutes
Increase in 1 hr PMP:	2.124	%
Interpolation of PMP %:	29.62	%

Adjusted t_c rainfall depth: 2.7 inch in t_c minutes

Rainfall estimate (i): 57.1 inch/hour

Rational Formula, q = Cia

C = is a dimensionless runoff coefficient
i = rainfall intensity (in/hour)
A = drainage area (acres)

C (Clay and Silt Loam,) =	0.600
i =	57.1 in/hour
Drainage Area Length =	386.0 ft
Drainage Area Width =	1.0 ft
A =	0.009 acres
q =	0.303 ft^3/sec/ft

STEPHENSON'S METHOD FOR SIZING RIPRAP BASED UPON PHASE II, ABT ET AL.	
Flow rate per unit width (q):	0.303 cfs/ft
Rockfill porosity (η_p):	0.35
Specific gravity (G_s):	2.7
Embankment slope (θ) :	40 %
Friction angle (Φ):	42 °
Empirical factor (C):	0.22
Olivier's constant (K):	1.8
Median stone size D_{50} :	0.53 ft
Median stone size D_{50} :	7 in

$$D_{50} = \left[\frac{q\,K\,(\tan\theta)^{7/6}\,\eta_p^{\;1/6}}{C\,(32.2)^{1/2}\left[(1-\eta_p)(G_s-1)\cos\theta\,(\tan\phi-\tan\theta)\right]^{5/3}} \right]^{2/3}$$

Rip Rap Gradation:

Based on the guidelines presented on page 53 from NUREG/CR-4620

W_{50min} =	18	lbs	D_{50min} =	7	in
W_{50max} =	50	lbs	D_{50max} =	10	in
W_{100min} =	44	lbs	D_{100min} =	10	in
W_{100max} =	80	lbs	D_{100max} =	12	in
W_{15min} =	5	lbs	D_{15min} =	5	in
W_{15max} =	10	lbs	D_{15max} =	6	in

Based on the guidelines presented on page 51 from NUREG/CR-4620, the rip rap layer thickness shall be 2.0 feet thick (minimum)

Based on the definitions presented on page 91 of NUREG/CR-4620, the rip rap layer will be rarely saturated due to the location of the rip rap on the landfill sideslopes. Therefore, the rip rap should be designed to the criteria for rip rap that is seldom saturated.

Rip rap quality shall meet the requirements for seldom saturated areas outlined in NUREG/CR-4620. Materials shall be oversized in accordance with the methods presented in NUREG/CR-4620. This calculation cannot be done until the rip rap quality has been determined.

CONCLUSIONS: The riprap used for sideslope protection must at a minimum meet the gradation shown in the attached gradation curve. The riprap layer will be at least two feet thick. Additional adjustments to the gradation curve will be necessary as testing is conducted on the riprap material.

SIDE SLOPE ARMOR FILTER CALCULATION SPREADSHEET

OBJECTIVE: Determine soil gradation for filter layer(s) between sideslope armor and the cover system

METHOD: Filter layers for the side slope were developed using NRC criteria as published in NUREG/CR-4620. The NRC uses two criteria:

1) $\dfrac{D_{15}\,(Filter\ )}{D_{85}\,(Base\ )} < 5$ This criteria is to prevent the migration of the filter material into the riprap

2) $\dfrac{D_{15}\,(Filter\ )}{D_{85}\,(Base\ )} < 10$ This criteria is to prevent the migration of the material below the filter into the filter

Gradation of Cover Materials		
Material	**D_{15} (mm)**	**D_{85} (mm)**
Sideslope Armor	130 - 150	230 - 300
Rye grass flats	-	0.01
Type 3 (biointrusion)	46 - 72	80 - 140
Type 2 filter material	0.54 - 2	18 - 50
Type 1 filter material	0.02 - 0.09	0.7 - 2.5

Using Type 3 material as a filter between the cover material and the sideslope armor

Criteria 1: $\dfrac{D_{15}\text{ (max) of armor}}{D_{85}\text{ (min) of Type 3}} = \dfrac{150}{80} = 1.88$

Type 3 material meets criteria 1 compared to sideslope armor

Criteria 2: $\dfrac{D_{15}\text{ (max) of Type 3}}{D_{85}\text{ (min) of Ryegrass}} = \dfrac{150}{0.01} = 15000.00$

Type 3 material does not meet criteria 2 compared to ryegrass flats material. Additional filter layers will be required

Using Type 2 filter material between the Type 3 filter material and ryegrass flats material. Because none of these materials are on the ground surface, only criteria two must be met.

Type 2 vs. Type 3: $\dfrac{D_{15}\text{ (max) of Type 3}}{D_{85}\text{ (min) of Type 2}} = \dfrac{72}{18} = 4.00$

Type 2 material meets criteria 2 compared to type 3 material

Ryegrass vs. Type 2: $\dfrac{D_{15}\text{ (max) of Type 2}}{D_{85}\text{ (min) of Ryegrass}} = \dfrac{2}{0.01} = 200.00$

Type 2 material does no meet criteria 2 compared to ryegrass flats material. Additional filter layers will be required.

Using Type 1 filter material between the Type 2 filter material and ryegrass flats material. Because none of these materials are on the ground surface, only criteria two must be met.

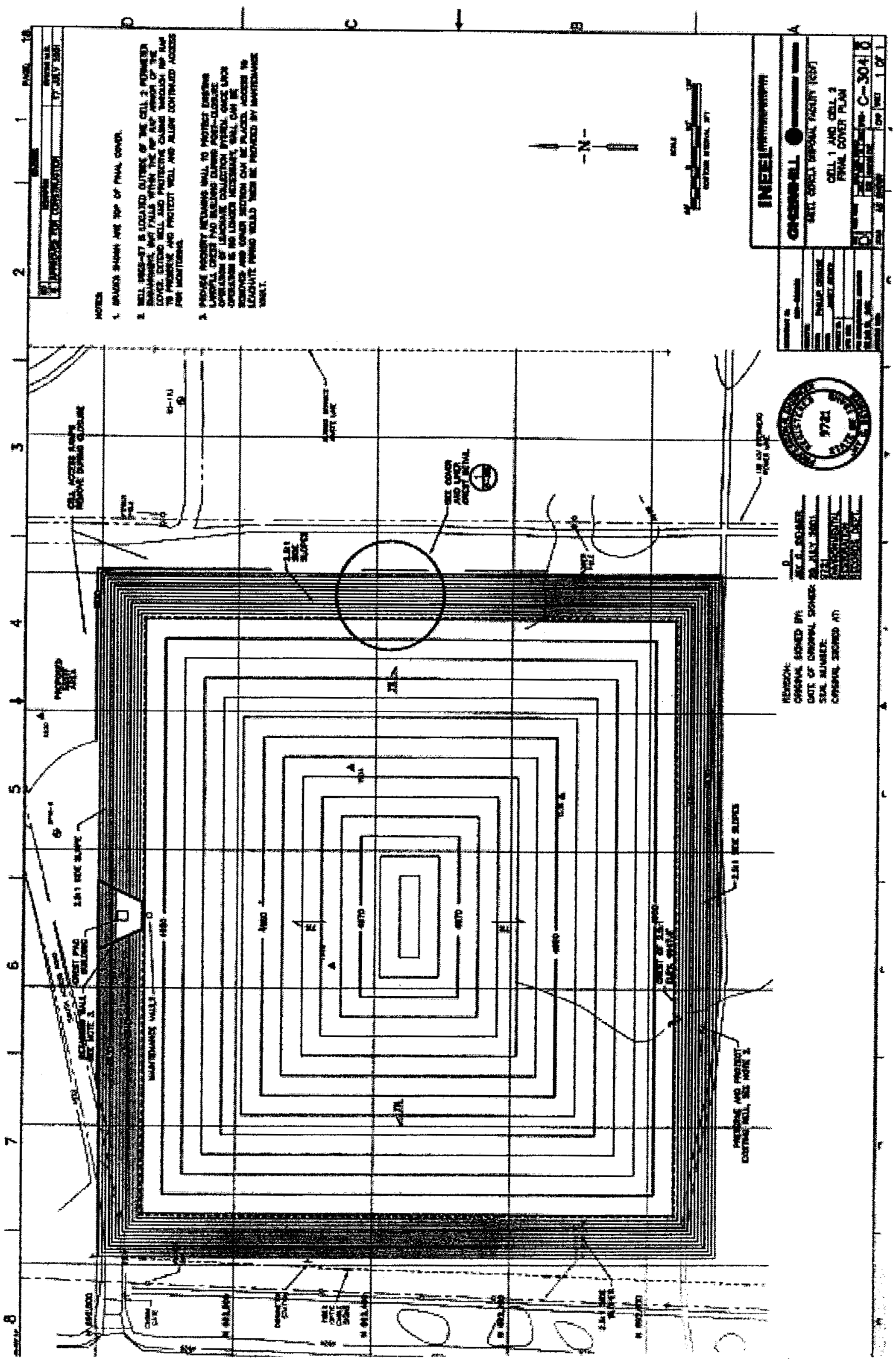
Type 1 vs. Type 2: $\dfrac{D_{15}\text{ (max) of Type 2}}{D_{85}\text{ (min) of Type 1}} = \dfrac{2}{0.7} = 2.86$

Type 1 material meets criteria 2 compared to type 2 material

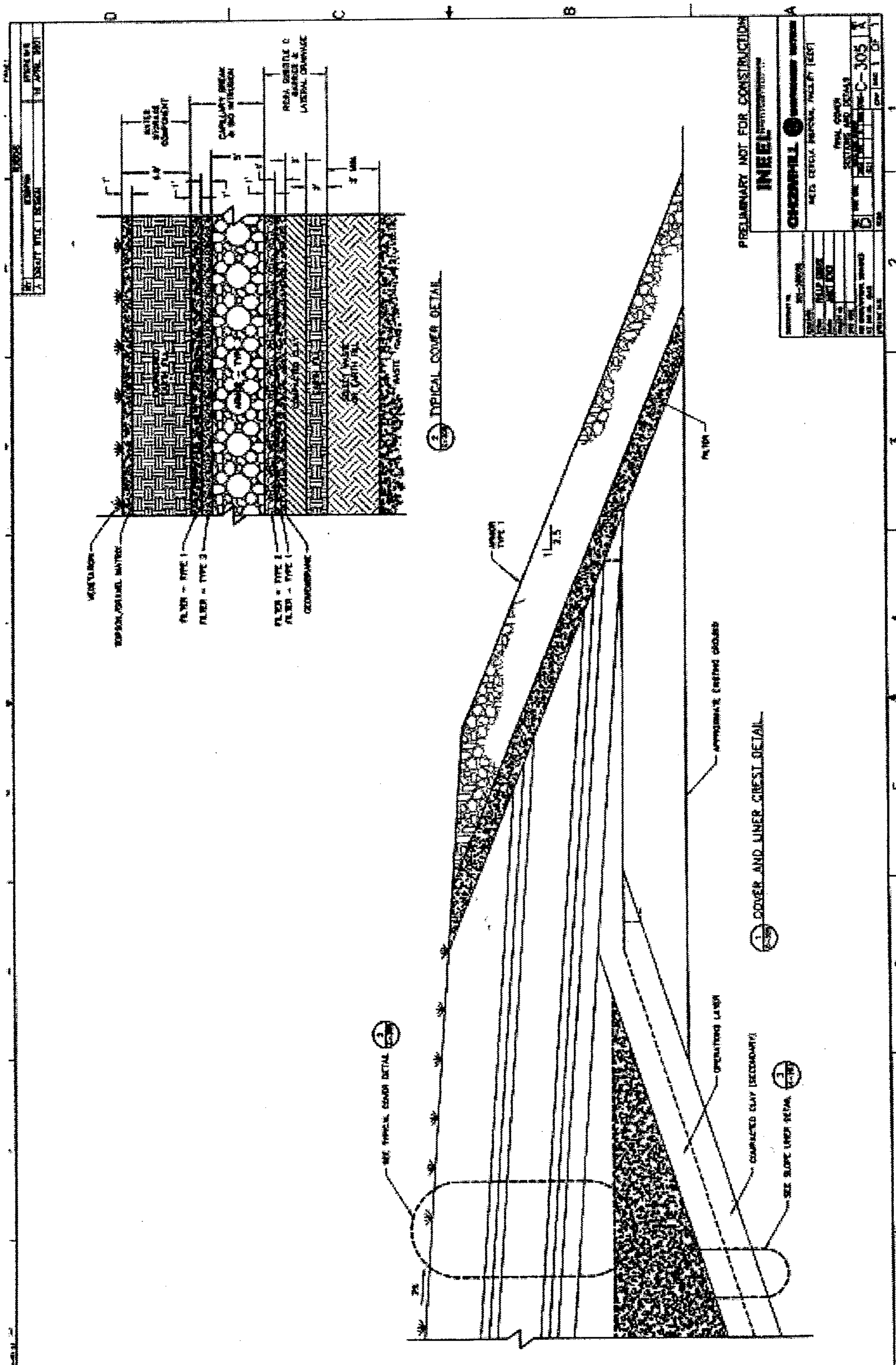
Ryegrass vs. Type 1: $\dfrac{D_{15}\text{ (max) of Type 1}}{D_{85}\text{ (min) of Ryegrass}} = \dfrac{0.09}{0.01} = 9.00$

Type 1 material meets criteria 2 compared to ryegrass flats material. No additional filter layers will be required.

Conclusion: Three filter layers will be required between the sidelslope armor and the cover materials. Type 3 armor will be placed directly below the riprap. Type 2 and Type 1 filter material will be placed below the Type 3 armor In accordance with NUREG/CR-4620, the thickness of each layer will be half the thickness of the sideslope armor with a minimum thickness of nine inches. Gradation requirements for each of the materials used are given in soil filter layer analysis.

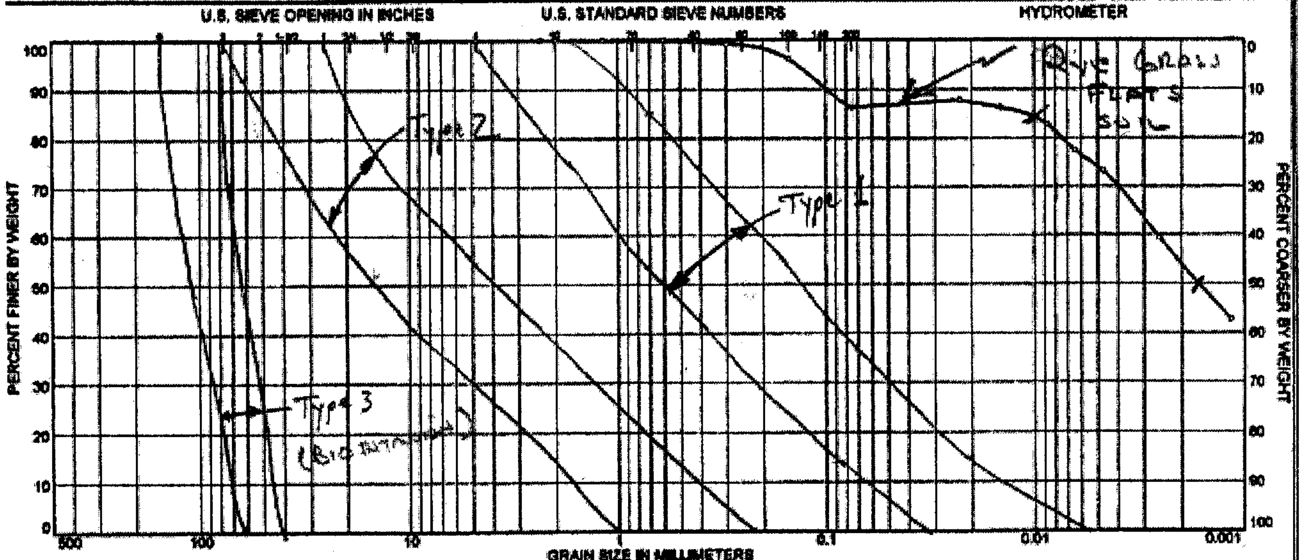


(See Drawing C-304 in Draft Final Drawings for more detail.)



(See Drawing C-305 in Draft Final Drawings for more detail.)

PARTICLE SIZE DISTRIBUTION TEST REPORT



% + 3"	% GRAVEL		% SAND			% FINES	
	COARSE	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	0.3	13.4	12.2	74.1

SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PL
WRRTF Area	#3-O #2	5.5'-6.0'	6-14-00	[illegible]	Lean clay	9.7%	39	14

Client Tom Borschel BBWI
Project INEEL CERCLA Disposal Facility (ICDF)
Project No. 3XD710130 Plate

INEL MATERIALS LAB

○ Sampled from WRRTF core #3, Borehole #3-O, core length 5.0' - 7.5'. Sampled by others.

APPLIED HYDROLOGY AND SEDIMENTOLOGY FOR DISTURBED AREAS

B.J. Barfield
Professor

and

R.C. Warner
Assistant Professor

Department of Agricultural Engineering
University of Kentucky
Lexington, Kentucky

and

C.T. Haan
Professor and Head

Department of Agricultural Engineering
Oklahoma State University
Stillwater, Oklahoma

Other methods are available in the form of empirical equations for estimating t_c. One such relationship is expressed by Kirpich (1940)

$$t_c = 0.0078\ L^{0.77}\ (L/H)^{0.385} \tag{2.58}$$

where t_c is in minutes, L is the maximum length of flow in feet and H is the difference in elevation in feet between the outlet of the watershed and the hydraulically most remote point in the watershed.

Several methods for estimating the lag time of a watershed are available. One simple method for lag time estimation is (U.S. Department of Agriculture, 1973):

$$t_L = 0.6t_c \tag{2.59}$$

The SCS has developed a lag equation based on natural watersheds

$$t_L = \frac{L^{0.8}(S+1)^{0.7}}{1900Y^{0.5}} \quad (50 \leqslant CN \leqslant 95) \tag{2.60}$$

where t_L is the lag in hours, L is the hydraulic length of the watershed in feet, S is given by equation 2.39 and Y is the average land slope in percent.

Many local studies have been conducted relating t_L or t_p or t_c to watershed physical characteristics. For example, Putnam (1972) in a study of 34 watersheds in North Carolina found the relationship

$$t_L = 0.49\left(\frac{L}{\sqrt{S}}\right)^{0.50} I^{-0.57} \tag{2.61}$$

where t_L is the basin lag in hours, L is the length of the main water course in miles, S is the main stream slope in feet per mile and I is fraction of impervious area. Here t_L was defined as the time from the center of mass of rainfall to the center of mass of runoff. Before an equation like 2.61 is used, care must be exercised to see that the conditions under which the equation was developed match the conditions of interest.

The duration, D, of the rainfall excess that is generally associated

with a unit hydrograph sho
The time to peak is given by

The base time of a unit
hydrologists use a base time
hydrograph models have a
proaches q = 0, so that the b

ESTIMATION OF PEAK F

The peak flow rate,
in a number of ways. Th
1972) uses the equation

$$q_p = \frac{484AQ}{t_p}$$

where q_p is the peak flov
and t_p is the time to peak i

As was the case for la
in an effort to relate q_p
any of these empirically
cability should be carefully

SHAPE OF UNIT HYDRO

If a short duration u
storm pattern, the actual s
as important as the time to
graph procedures actually
mate shape of the unit h
hydrograph is one inch.

The U.S. Corps of E
be used as an aid in det
The curves in Figure 2.3
at flow rates equal to 0.
the widths at these point
width occurs prior to the p

Table 2.27 Runoff Coefficients (continued)

Rural Areas

Topography and Vegetation	Soil Texture: Open Sandy Loam	Clay and Silt Loam	Tight Clay
Woodland			
Flat 0-5% slope	0.10	0.30	0.40
Rolling 5-10% slope	0.25	0.35	0.50
Hilly 10-30% slope	0.30	0.50	0.60
Pasture			
Flat	0.10	0.30	0.40
Rolling	0.16	0.36	0.55
Hilly	0.22	0.42	0.60
Cultivated			
Flat	0.30	0.50	0.60
Rolling	0.40	0.60	0.70
Hilly	0.52	0.72	0.82

The rainfall intensity used in equation 2.68 should be for the desired frequency and have a duration equal to the time of concentration of the area. The estimation of the time of concentration has been previously discussed under the section on time parameters for runoff hydrographs. The reason for selecting an i with a duration of t_c is that if a shorter duration is selected, the entire basin will not be contributing runoff and the i will be too large. If a duration greater than t_c is selected, i will be too small since a shorter duration rainfall will produce runoff from the entire basin and will have a higher intensity. The rainfall intensity-duration-frequency curves of Figure 2.17 can be reviewed to see that as the duration increases for a given frequency, the average intensity decreases.

As with any estimation procedure, considerable care should be exercised when applying the rational equation to estimate peak flows. For instance, the location of relatively impervious areas with respect to the point of flow estimation must be carefully considered. If flow from an impervious area has to cross an infiltrating area such as grass, the flows may be greatly reduced. If large impervious areas are present, they should be analyzed as separate units. The reason for this can be seen by considering the situation shown in Figure 2.39. In case A the impervious area is next to the outlet, while in case B the grass area is next to the outlet. Straightforward application of the rational

equation would result in the sa
and the weighted C would be t

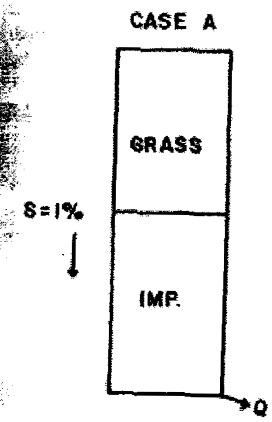


Figure 2.39. H

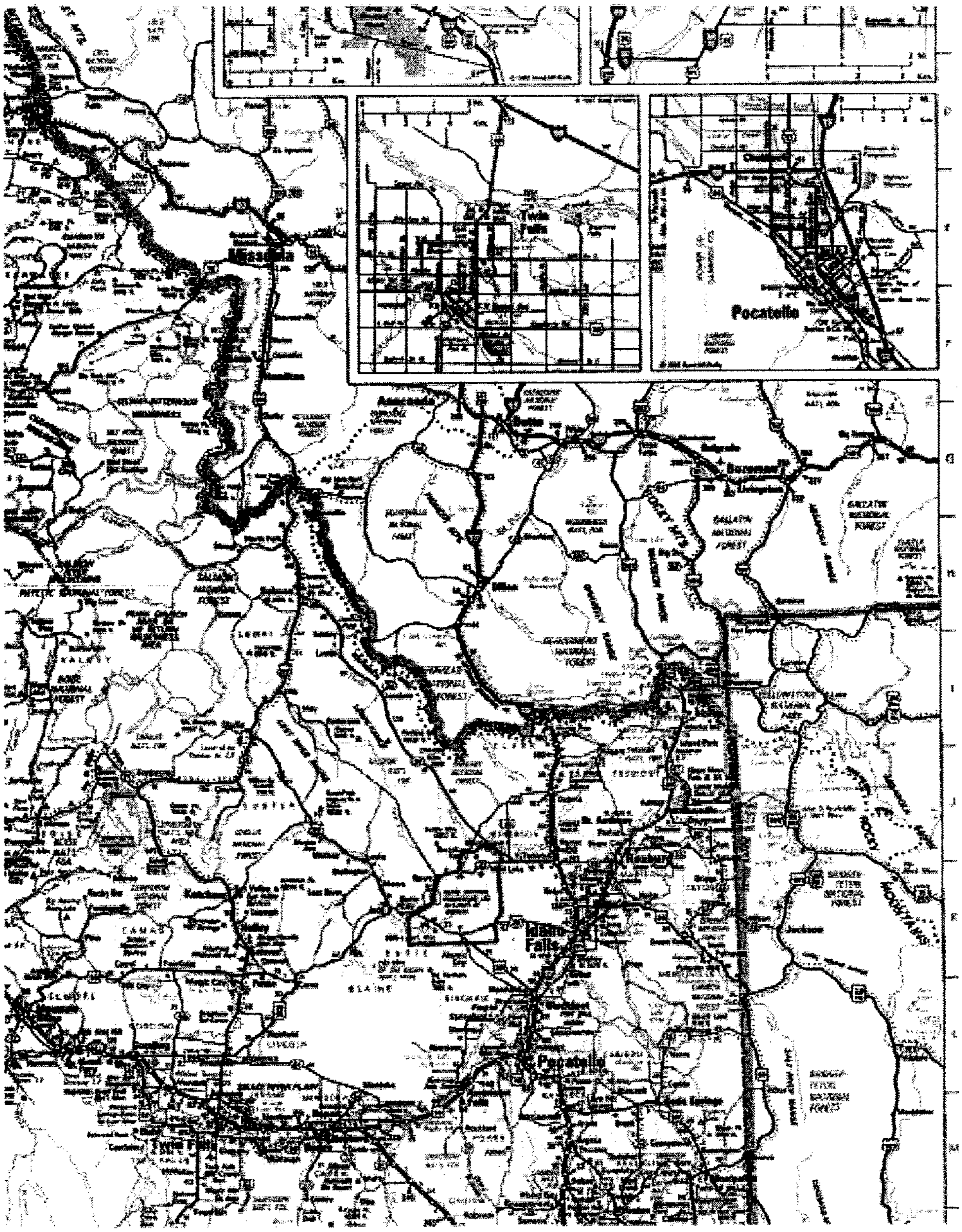
A closer look at case A.
the peak flow from the imper
estimated for the whole area
2.57 we estimate a flow time
Using a similar procedure, a
estimated for the imperviou
minutes. A weighted C is

$$\overline{C} = 1/2(0.9 + 0.2) = 0.55$$

A 10-year, 15-minute rain at
Thus,

$$q_{total} = 0.55(4.7)\ A = 2.5$$

Considering only the impervio
corresponding i is 6.8 iph


Pocatello

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

U.S. DEPARTMENT OF INTERIOR
BUREAU OF RECLAMATION

U.S. DEPARTMENT OF ARMY
CORPS OF ENGINEERS

HYDROMETEOROLOGICAL REPORT NO. 57
(SUPERCEDES HYDROMETEOROLOGICAL REPORT NO. 43)

PROBABLE MAXIMUM PRECIPITATION - PACIFIC NORTHWEST STATES
Columbia River (including portions of Canada), Snake River and Pacific Coastal Drainages

Prepared By

E. M. Hansen, D. D. Fenn, P. Corrigan and J. L. Vogel
Water Management Information Division
Office of Hydrology
National Weather Service
and
L. C. Schreiner and R. W. Stodt
Flood Section, Surface Water Branch
Earth Sciences Division
Bureau of Reclamation

Published by
National Weather Service
Silver Spring, MD
October 1994

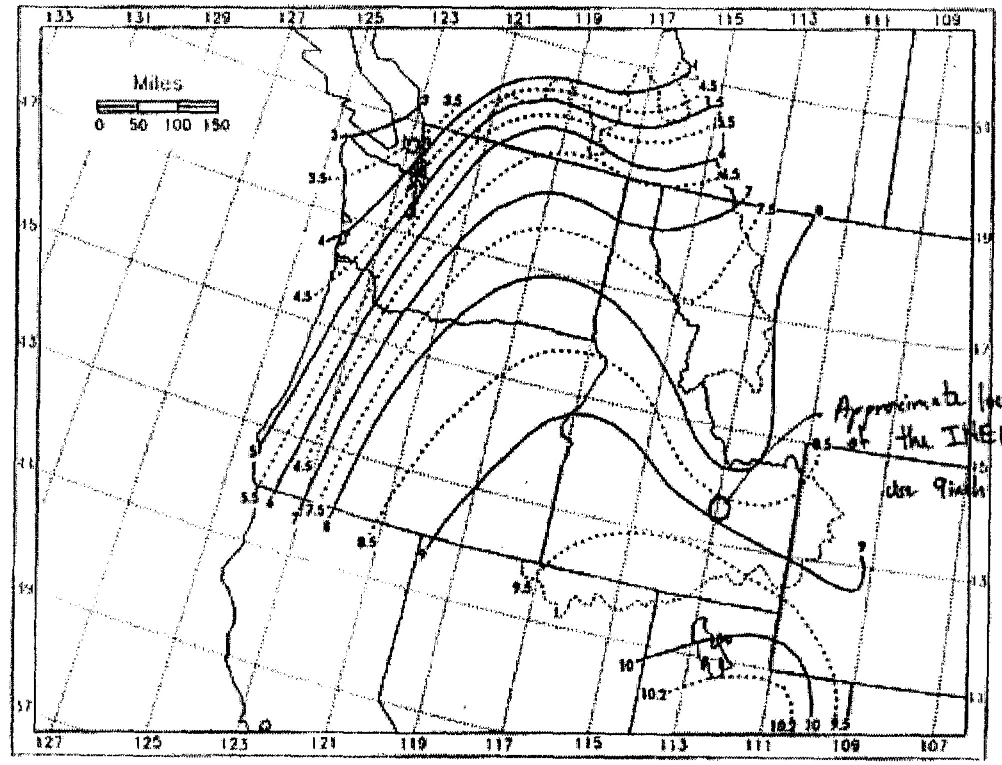
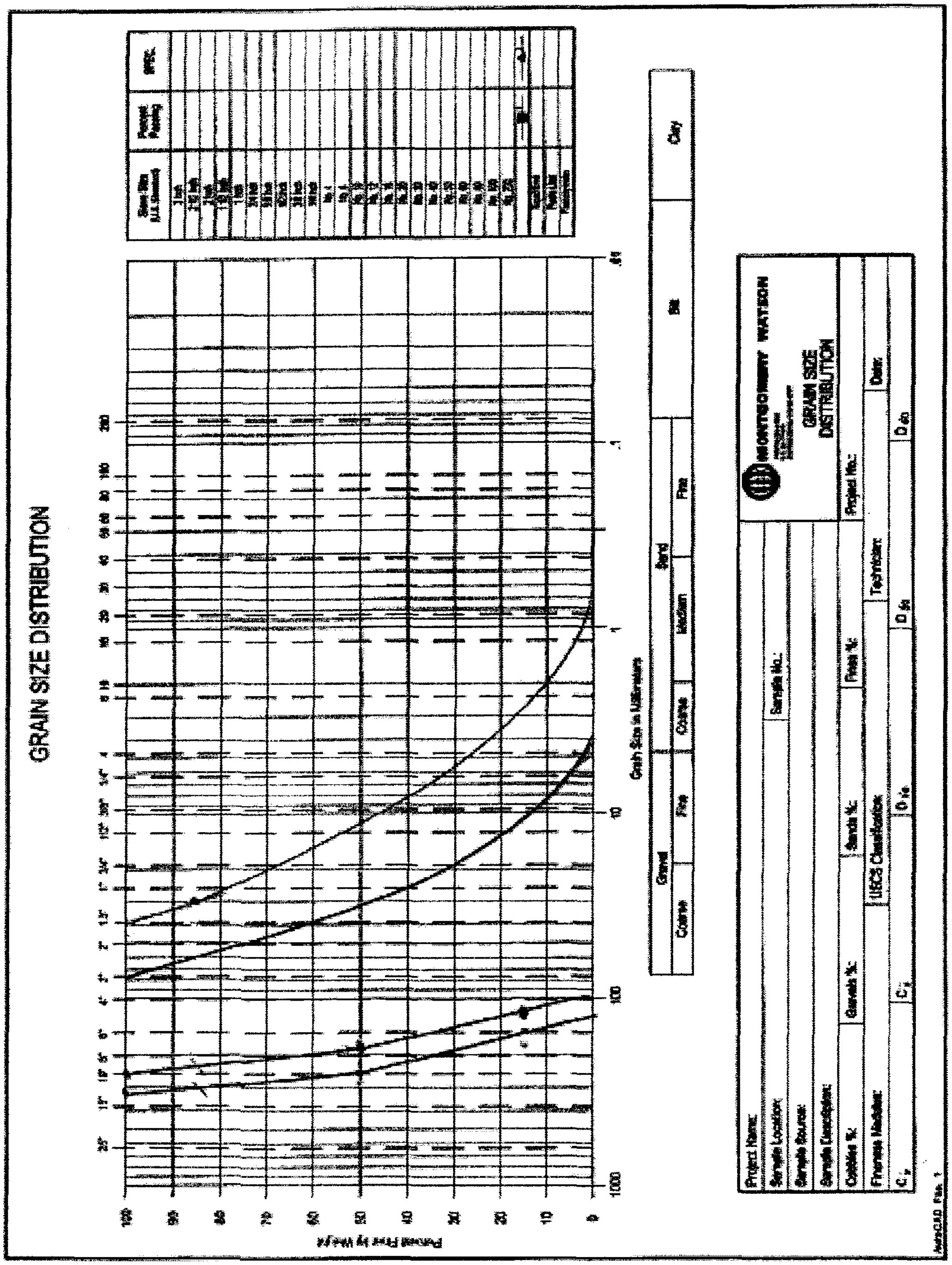


Figure 15.36.--1-hr 1-mi² local storm PMP in inches for elevations to 6000 ft.


GRAIN SIZE DISTRIBUTION
Grain Size in Millimeters
Gravel
Coarse
Fine
Sand
Coarse
Medium
Fine
Silt
Clay
MONTGOMERY WATSON
GRAIN SIZE DISTRIBUTION
Project Name:
Sample Location:
Sample Source:
Sample Description:
Cobbles %:
Gravels %:
Sands %:
Fines %:
Fineness Modulus:
USCS Classification:
Technician:
Date:
Sample No.:
Project No.:
Percent Passing
SPEC.

Appendix G

Bio-Intrusion Analysis

FINAL COVER BIOINTRUSION ANALYSIS

OBJECTIVE: Determine whether biointrusion will be a problem with the current cover design

METHOD: Biointrusion refers to intrusion into the disposed waste either by plants or animals. Determination of potential problems related to biointrusion was based on research completed at the Hanford DOE site and at the INEEL. At the INEEL there are deep rooting plants and burrowing animals that could potentially intrude on the waste. The deep rooting plants consist of sage brush and the following are the animal types that exist at the INEEL:

Badger
Coyote
Townsend Ground Squirrel
Ants

Plant Biointrusion

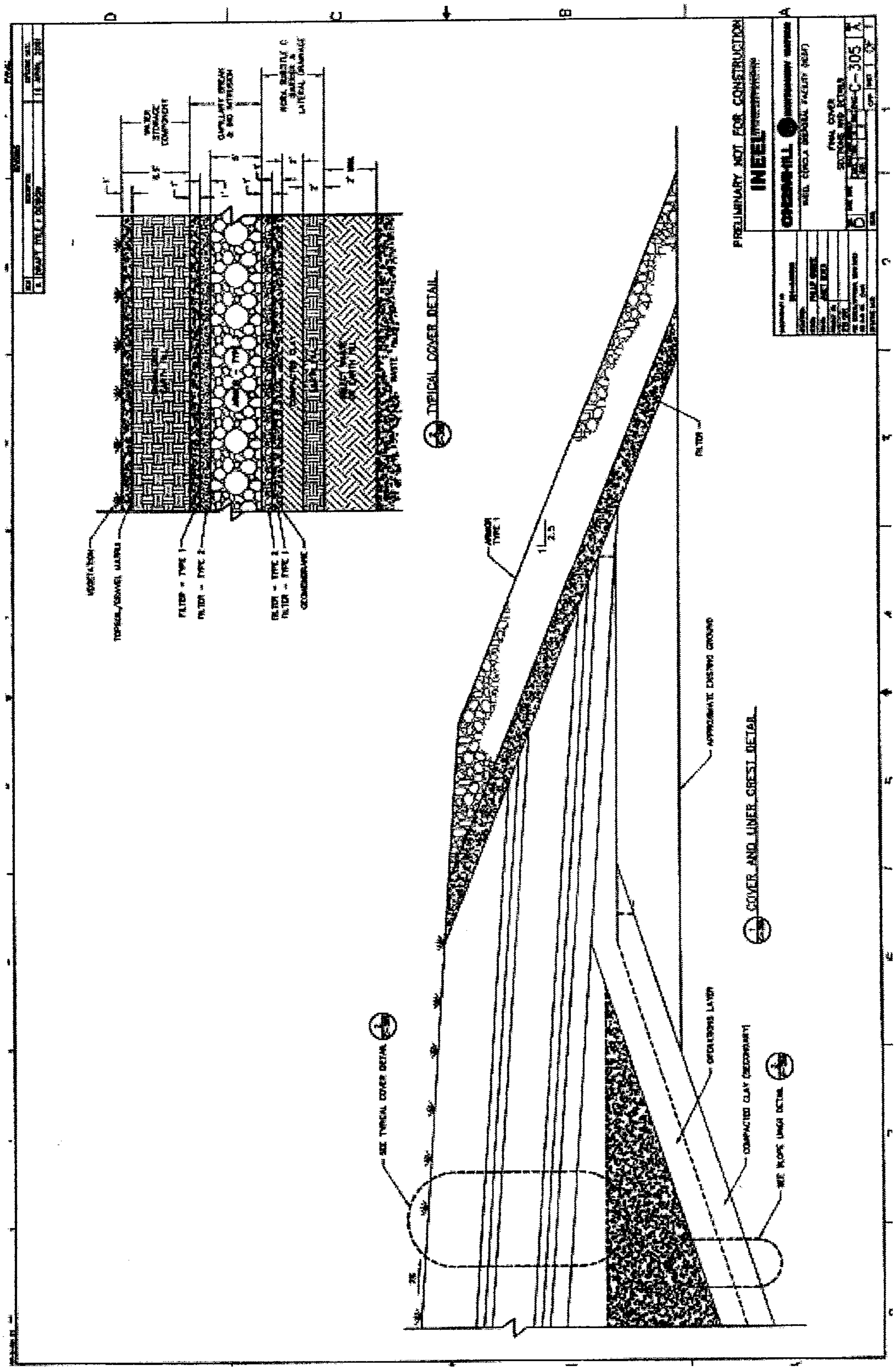
The current cover thickness at the ICDF is 17.5 feet. The only plant which is deep rooting on the INEEL is sage. Due to this great thickness of the cover system it is not anticipated that plant roots could fully penetrate this thickness. In addition to the great thickness, the plant roots would first have to go through 4.5 feet of capillary break/biointrusion layer. Research has shown that plant roots typically do not penetrate into zones where there is no available moisture for the plant to use. Due to the coarse nature of the biointrusion layer, this material does not have any moisture available for plant roots; therefore, this layer inhibits plant root growth through this zone. In addition, a 60 mil HDPE geomémbrane will be placed below the biointrusion layer. This nonporous material is expected to further deter plant root growth any deeper.

Animal Biointrusion

The attached documents indicate that the burrowing mammals mentioned above typically burrow only to about 3.3 feet (1 meter) deep. The biointrusion layer is located 11 feet below the ground surface. Therefore mammals will need to burrow over 3 times their normal burrowing depth just to get to the biointrusion layer. Once they get to the biointrusion layer, they need to burrow through 2.5 feet of coarse gravel and fine cobble material (1 to 2 inch diameter) to get through this layer. This type of material has been documented to inhibit animal burrowing (Richardson, Geosynthetic Design Guidance for Hazardous Waste Landfill Cells and Surface Impoundments).

The animal that has been documented as the deepest burrowing animal indigenous to the INEEL is the harvester ant. Ant burrows at the INEEL have been found up to 6 feet deep. Ant burrows at other locations in the United States have been found to depths of 13.2 feet. Based on this data, the total cover thickness of 21.5 feet is much greater than the maxim observed ant burrowing depth at the INEEL. In addition, research has shown that coarse gravel and cobble material sharply reduces ant burrowing. It appears that ants will burrow to depth where soil thermal and moisture fluctuations are relatively constant. If ant colonies have unrestrained horizontal range to burrow, it is anticipated that they will have no incentive to burrow through the biointrusion layer. A HDPE geomembrane will be installed below the biotic barrier, this material is expected to further inhibit any ant burrowing into the waste material.

CONCLUSIONS: Based on the attached research it is highly unlikely that either plant or animals will be able to penetrate the full depth of the cover due to its large thickness and due to the biointrusion layer. Therefore the cover section as currently designed addresses the concerns of biointrusion.
Based on research, the Type 3 material should consist of gravel and cobble material between 2 and 5 inch diameter



(See Drawing C-305 in the ICDF Draft Final Drawings for more details.)

GEOSYNTHETIC DESIGN GUIDANCE
FOR
HAZARDOUS WASTE LANDFILL CELLS AND SURFACE IMPOUNDMENTS

by

Gregory N. Richardson
Soil & Material Engineers, Inc.
Cary, North Carolina 27511

Robert M. Koerner
Geosynthethic Research Institute
Drexel University
Philadelphia, Penn. 19014

Contract No. 68-03-3338

Project Officer:
Robert Hartley
Land pollution Control Division
Hazardous Waste Engineering Research Laboratory
Cincinnati, OH 45268

HAZARDOUS WASTE ENGINEERING RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OH 45268

(December 1987)

Biotic Barrier

In some locations, a biotic barrier may be advisable to reduce the potential for intrusion of animals (e.g., gophers, mice, etc.) or plant roots which can disrupt the integrity of the hydraulic barrier layer and increase percolation of surface water through burrow tunnels or root channels. Hakonson (1986) found a biotic barrier of 60 centimeters (28 inches) of 7.5 to 12-centimeter cobblestone overlain by 30 centimeters (12 inches) of gravel was effective. The cobblestones were of sufficient mass to deter burrowing animals and the large void spaces, which lacked water and nutrients, acted as a barrier to plant root developments. Research is not presently available on an optimum depth for a barrier layer; therefore, the actual thickness of the biotic barrier should be based upon site characteristics, including expected intruders, depth of plant roots, etc. Cline (1979) also reported that the use of cobbles was effective in limiting rodent penetration and also described the use of root toxins to limit the penetration of plant roots.

Past research in West Germany, Rumberg (1985), indicates that a significant danger exists to membranes from burrowing below the facility. Studies were performed with beavers and rodents to evaluate the susceptibility of various membranes to damage from burrowing. Some membranes such as soft PVC actually attracted the rodents and encouraged damage. The best performance for an unprotected membrane was in the thicker sheets of polyethylene. These rigid sheets are difficult for animals to bite. This study led to the development of test procedures that use mice (arvicola terrestris) to predict the resistance of sheet to penetration. Protective measures such as wire or glass mesh may offer a partial solution.

GAS COLLECTION and VENTING

It is rarely necessary to design for control of gases when covering a controlled hazardous waste site. Gases are evolved wherever decayable (biodegradable) organic matter is buried; thus gas control is typically a problem for sanitary but not hazardous waste landfills. Where municipal and hazardous wastes are consigned at the same site, a gas problem is likely. Where no decayable matter is buried, gas will probably not be a problem. The following discussion of gas generation is intended to provide a general review of the gas generation mechanism and not to imply that dramatic quantities of gas are to be anticipated at controlled hazardous waste facilities.

Within a few months of closure of a landfill containing organic refuse, anaerobic decay conditions stabilize, and thereafter only two gases are produced in appreciable quantity: methane (CH_4, about 55 percent by volume) and carbon dioxide (CO_2, about 45 percent by volume). Trace quantities of other gases may also be produced. The rate of waste gas production decreases steadily, but some production may persist for many years. In general, the methane gas being lighter than air is the more significant problem since it will interface with the synthetic capping system.

WHC-EP-0650

UC-902

Permanent Isolation Surface Barrier: Functional Performance

N. R. Wing

Date Published
October 1993

Prepared for the U.S. Department of Energy
Office of Environmental Restoration and
Waste Management

Westinghouse
Hanford Company
P.O. Box 1970
Richland, Washington 99352

Hanford Operations and Engineering Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

The maximum allowable subsidence that a barrier can withstand and still remain functional needs to be determined. Although the use of subsidence control measures (e.g., dynamic compaction and in situ grouting) is expected to reduce significantly the magnitude of subsidence experienced; for certain types of waste, subsidence events cannot be expected to be reduced to zero. Consequently, there is a need to determine the magnitude of subsidence that a barrier is capable of withstanding and still function as designed.

Field and laboratory tests will be performed to determine the barrier's ability to withstand subsidence events of various magnitudes. As appropriate, computer simulation models also may be used in the assessment. The results of the tests and modeling will be used to formulate barrier design standards and waste acceptance criteria. For a permanent isolation barrier to be employed, end users would be required to provide waste forms that comply with the established barrier design standards and waste acceptance criteria for subsidence.

The final permanent isolation barrier design will need to provide some measure of assurance that it can survive and function as designed following the potentially disruptive events discussed previously. Studies to ensure that current barrier designs will provide the level of physical stability needed have not yet been conducted but are scheduled for the future. Any permanent isolation barrier design modifications that are needed because of the results of the studies will be incorporated into future designs, as applicable.

3.2 BIOINTRUSION CONTROL

Protective barriers must be designed to protect wastes from the intrusion of deep-rooting plants and burrowing animals. The protective barrier design configurations being considered to control these potential problem areas are discussed in the following subsections.

3.2.1 Plant-Root Intrusion Control

Barrier designs are intended to control plant roots from the following:

- Disrupting the textural break interface between the fine-soil layer and the coarser materials below
- Disturbing the low-permeability layers
- Penetrating into the waste zone beneath the protective barrier.

The control of plant-root intrusion is accomplished primarily by the materials used to construct protective barriers (e.g., fine soil, sand, gravel, cobble, basalt riprap, and asphalt). These barrier construction materials are expected to provide an effective deterrent to plant-root intrusion.

3.2.1.1 Plant Roots and the Capillary Break Interface. Plant roots need water to survive. Because the capillary barrier is expected to be effective in keeping water from moving past the fine-soil/sand interface, the plant-available water below the capillary barrier is expected to be limited enough so that plant root growth will not be sustained.

This phenomenon has been observed in a clear-tube lysimeter at the FLTF. In the fall of 1988, a deep-rooting sagebrush was planted in the surface soils of the clear-tube lysimeter. As the sagebrush matured, the root system of the plant developed into a network that penetrated the fine-soil layer. However, as the roots reached the textural interface between the fine soils and the coarser sands below, their growth was stopped. The roots next to the inside wall of the clear-tube lysimeter were observed to penetrate just a few millimeters into the sand. No plant roots were observed to penetrate past the sand layer and into the graded filter.

The plant lived for more than three yr within the lysimeter but appeared stressed by late 1991 and died in 1992. During its 3-yr life, while the lysimeter was subject to 2 yr of 2X precipitation and 1 yr of 3X precipitation, no water was observed to move below the fine-soil layer. In this lysimeter, the capillary barrier was effective in keeping plant roots from moving past the fine-soil/sand interface, even under conditions simulating a wetter climate.

However, as mentioned previously, the capillary barrier concept does have its limits. During the winter of 1992/1993, when record snowfalls were recorded at the Hanford Site, the storage capacity of the fine-soil reservoir was exceeded. The routine supplemental irrigation treatments, when combined with the unusually large amount of precipitation received during that winter, resulted in greater than 3X (>520 mm) precipitation being added to the clear-tube lysimeter. The net result was that the moisture in the lysimeter wetted the sand and began draining past the capillary barrier. The sublayer filter material and riprap materials were visibly wetted but no drainage occurred from the base of the lysimeter. [The lysimeters with vegetation did not drain even though they received the same amount of moisture (520 mm). It is reasonable to assume that, had the sagebrush been living during the winter of 1992/1993, the storage capacity of the soil would not have been exceeded and the underlying graded filter materials would have remained dry.]

In March of 1993, following the unusually wet winter, another sagebrush was planted in the clear-tube lysimeter. By early June the roots of the sagebrush grew past the fine soil/sand interface and into the graded filter — following the water that had percolated past the capillary barrier. By July, the soils in the subject clear-tube lysimeter were dried out by the combined effects of surface evaporation and plant transpiration. As a result, the moisture content in the soils of the lysimeter has been reduced such that the effectiveness of the capillary barrier has been restored. The plant roots that penetrated below the capillary barrier probably will not be able to survive as the plant-available water continues to be depleted. It will be interesting to observe how this lysimeter performs over the next few years. Is the capillary barrier restored to its original effectiveness? Do the plant roots below the capillary barrier die as expected? Do the plant roots that have penetrated the capillary barrier (even if they are dead) provide a preferential pathway for moisture drainage? Destructive sampling of large vegetated lysimeters and observations on the prototype barrier will further define the ability of the capillary barrier to resist root penetrations. As the information from this and other lysimeters and studies becomes available, it will be incorporated into future barrier designs as needed.

3.2.1.2 Plant Roots and the Low-Permeability Layers. The textural break at the capillary interface between the fine soil and sand layers is expected to substantially limit root penetration into the lower portion of the barrier profile. However, if plant roots are able to penetrate through the fine-soil layers, the coarser materials used in the lower portions of the barrier profile will provide an additional deterrent to plant-root intrusion. As an example, the use of gravels and fractured basalt below the capillary break will probably discourage plant-root intrusion by limiting plant-available water. Consequently, it is not expected that plant roots will come into direct contact with the low-permeability layers that lie beneath the sands, gravels, and fractured basalt. However, should the plant roots come into direct contact with the low-permeability materials, the compacted asphalt is expected to limit root penetration deeper into the barrier profile. Previous work performed by PNL, using asphalt layers on uranium mill tailing sites, indicated that compacted asphalt emulsion layers are effective in preventing root intrusion (Baker et al. 1984). Tests have been conducted at the STLF to verify the effectiveness of asphalt layers in preventing root intrusion under Hanford Site conditions.

3.2.1.3 Plant Roots and the Waste Zone below the Barrier. In addition to the barrier construction materials and the properties derived from their placement (textural break, coarse materials, and compacted asphalt layers), the sheer thickness of the protective barrier is anticipated to exceed the maximum rooting depths of most plants expected to grow on the barrier. The thickness of current permanent isolation barrier designs is around 5 m (16.4 ft). The thickness of the barrier, in addition to the thickness of the overburden materials backfilled over the waste zone before barrier construction, provide a substantial buffer between the barrier's surface and the upper portions of the buried wastes. Root intrusion tests are an ongoing task in the BDP. Results from these tests will be incorporated into future designs.

3.2.2 Burrowing Animal Intrusion Control

As with plant root intrusion, the intrusion of burrowing animals could adversely affect barrier performance in the following ways:

- The disruption of critical barrier interfaces
- The penetration into and transport of contaminants from the waste zone
- The creation of preferential pathways for water to migrate deeper into the barrier profile
- The deposition of loose soil castings on the barrier surface with potential for accelerated soil erosion (barrier degradation).

The following paragraphs will discuss what can be done to mitigate these potential problems.

3.2.2.1 Burrowing Animals and the Disruption of Critical Barrier Interfaces. As discussed previously, it is recommended that the fine-soil layer that serves as a water retention medium be at least 1.5 m (4.9 ft) thick. Current designs use a fine-soil layer 2.0 m (6.6 ft) thick. Because the fine-soil layer is placed directly over a coarser sandy layer to create the capillary break, an animal would have to burrow down 2 m (6.6 ft) before contacting the capillary break interface. The results of a literature survey show that virtually all animals that currently inhabit or are expected to inhabit the Hanford Site during the design life of the permanent isolation barriers normally do not have a need to burrow deeper than 1 m (3.3 ft) (Gano and States 1982). Favorable biological conditions (i.e., food, shelter, moisture, soil temperature, etc.) for most of the animals are found within the top 0.5 to 1 m (1.6 to 3.3 ft) of the earth's surface. Because there is no need or incentive for these animals to burrow deeper than 2 m (6.6 ft) and because the layers below the fine soil are "hostile" (e.g., dry, sterile, composed of large rocks, etc.), the animals probably will not expend the additional energy required to dig deeper into the barrier profile.

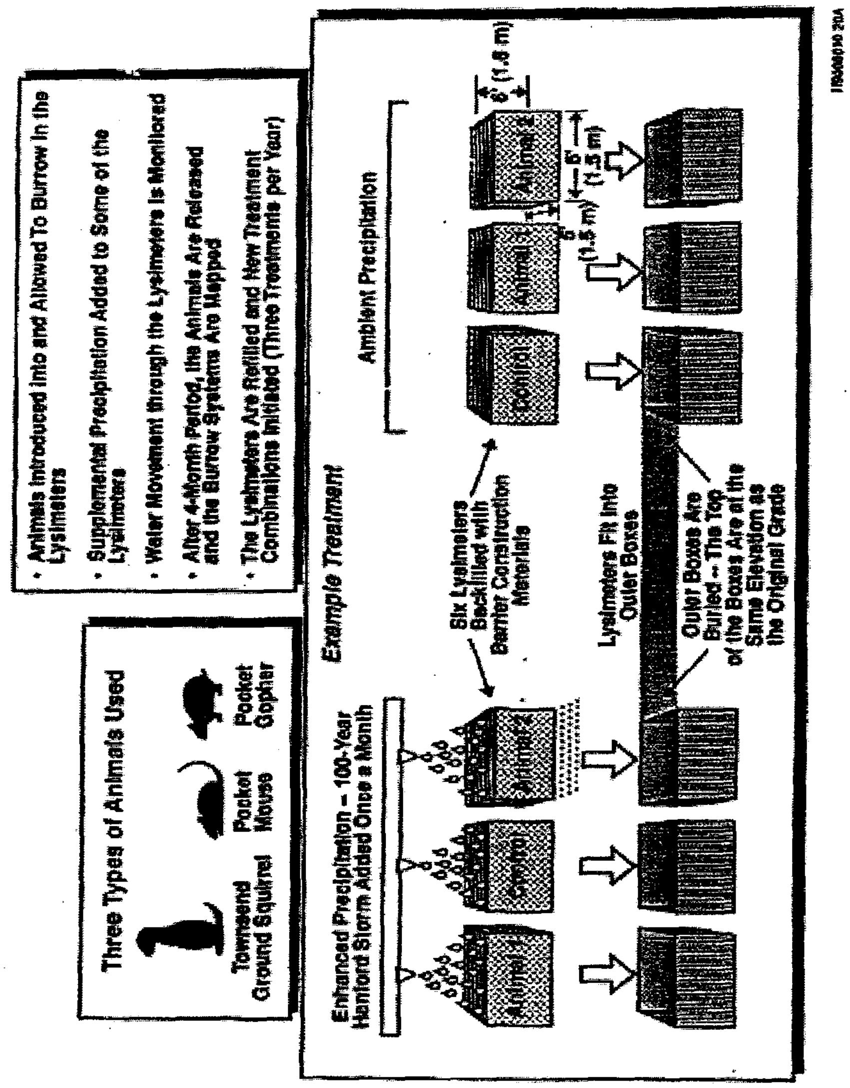
There are animals on the Hanford Site, however, that are known to have burrowed deeper than 2 m (6.6 ft), particularly the Western harvester ant. If burrowing animals such as ants were to penetrate the top fine-soil layer of the barrier, they probably would be deterred by the highly compacted asphalt layers.

3.2.2.2 Burrowing Animals and Their Ability To Penetrate into Buried Wastes. As was the case for plant-root intrusion, the thickness of the barrier in addition to the resistance offered by the low-permeability layer (asphaltic concrete mix) and the basalt layers (crushed and fractured layers) are expected to further discourage animals from burrowing through the barrier and into the waste zone.

3.2.2.3 Burrowing Animals and the Creation of Preferential Pathways for Water Infiltration. Tests have been conducted to assess the impact of burrowing animals on the infiltration and percolation of water through protective barriers (Cadwell et al. 1989, Landeen et al. 1990, Landeen 1990, Landeen 1991). During the early years of the BDP, concerns were raised that the presence of animal burrows may provide preferential conduits through which infiltrating water could bypass the fine-soil layer of the permanent isolation barrier and subsequently migrate deeper into the barrier and possibly into the waste zone below. The results of the tests that have been conducted (for both small and large mammals) have provided somewhat contrasting results.

An Animal Intrusion Lysimeter Facility (AILF) was constructed in FY 1988 to assess the effects of small-mammal burrows on the infiltration of meteoric water through protective barriers. The AILF, located adjacent to the HMS, consists of two outer boxes buried in the ground such that the top of each of the boxes is flush with the original grade. These outer boxes serve as receptacles for six animal intrusion lysimeters; three lysimeters are housed in each outer box (Figure 3-14). Each of the lysimeters has been engineered structurally so that it can be lifted out of the outer boxes with a crane.

Figure 3-14. Animal Intrusion Lysimeter Facility: Experimental Design.



The side walls of the lysimeters also have been engineered such that they can be disassembled.

The lysimeters at the AILF were designed such that a series of 3- to 4-month long tests could be conducted at the facility. The following description illustrates how the lysimeters in the facility are used to assess the effects of animal intrusion on the infiltration of water through a protective barrier. Each of the animal intrusion lysimeters is filled with soil excavated from McGee Ranch. (McGee Ranch is the borrow pit site that has been established for obtaining fine soils with which to construct protective barriers). Small-burrowing mammals, common to the Hanford Site, are introduced into the lysimeters and allowed to burrow for a 3- to 4-month period of time. During this 3- to 4-month period, supplemental precipitation is added to three of the six lysimeters using a rainfall simulator (rainulator). The supplemental precipitation is applied once a month at a rate equivalent to a 100-yr storm event at the Hanford Site (0.55 in. [0.14 cm] of water -- it takes the rainulator 13 minutes to apply this amount. See Section 3.1.1.2 for a discussion of the 100-yr storm).

Soil moisture samples are taken at the beginning of the experiment as well as at the conclusion of the 3- to 4-month testing period. Throughout the duration of the test, soil moisture measurements also are taken with a neutron moisture probe. These neutron moisture probe measurements, along with the soil moisture samples taken at the beginning and end of a testing period, enable a determination to be made of the changes in the soil moisture content throughout the barrier profile.

At the conclusion of the testing period, the burrowing animals are released and the burrow networks throughout the lysimeters are mapped. The changes in soil moisture content can then be correlated with the burrow networks created by the small mammals.

The following trends have been observed from the tests conducted to date with small mammals at the AILF (Landeen 1991).

- During the summer months, more water is lost from plots with animal burrows than from the control plots (no animal burrows).
- During the winter months, both the plots with animal burrows and the control plots gain water.
- There is no indication of water infiltration below ~1 m (36 in.) even though burrow depths always exceed ~1.2 m (48 in.).

The lack of significant water infiltration at depth and the overall water loss in the lysimeter plots is occurring despite the following worst-case conditions:

- No vegetative cover (no water loss through transpiration)
- No water runoff (all incipient precipitation is contained)
- The burrow densities in the lysimeters are greater than the burrow densities found in "natural" settings

* Extreme rainfall events applied frequently (three 100-yr storm events in 3 months)

* Animals burrow deeper in the lysimeters than in "natural" settings.

Three preliminary conclusions have been drawn from the tests conducted to date at the ALLF. Overall water loss appears to be enhanced by (1) a combination of soil turnover and subsequent drying, (2) ventilation effects from open burrows, and (3) high ambient temperatures.

Similar water loss results have been observed for experiments conducted on existing large-mammal burrows found in a natural setting on the Arid Land Ecology Reserve at the Hanford Site. The large-mammal burrows studied were excavated by coyotes and badgers in search of prey. The soils into which the burrows were excavated consist of a silt loam similar to the sediments found at the McGee Ranch.

One of the studies conducted with the large-mammal burrows demonstrated that the burrows are very effective in rapidly accumulating runoff water as it moves across the soil surface via overland flow. Cadwell and others provided the following observations (Cadwell 1991).

> Studies...were conducted to quantify the amount of runoff entering badger burrows. A runoff generator was used to apply water along the slope above badger burrows. Results from these studies showed that burrows intercept a considerably greater amount of runoff than expected based solely on the surface area of the burrow. Thus, it seems clear that runoff may either be funneled into burrows, or there may be increased infiltration in the soil around burrow openings or both.

Neutron probe access tubes were installed around the periphery of several of the large-mammal burrows as well as in nondisturbed areas adjacent to the burrows. The effects of large-mammal burrows on water infiltration and percolation were studied by comparing the moisture contents of the soils around the burrows with the "control" plots (the nondisturbed areas adjacent to the burrows). In some cases, supplemental precipitation was added to the burrows being studied as well as to the "control" plots. The researchers provided the following observations from the tests that were conducted (Cadwell 1991).

> Observations made with simulated rainfall in previous years showed that large burrows dug by coyotes and badgers can divert surface water deep into barrier soils. Measurements made in FY 1989 and FY 1990 document that under natural rainfall, precipitation penetrates deep beneath and around badger burrows. However, the water is subsequently withdrawn...In disturbed soils near burrows, the vigorous growth of invading plant species may result in the preferential extraction of water through plant transpiration. Enhanced evaporation from the soil surfaces exposed by burrowing may also preferentially remove soil water near burrows. Our data showed that the soil beneath burrows in mid-summer was actually drier than in adjacent areas away from burrows. Vegetation sampling showed that plant densities (mustards) were significantly greater in the

> vicinity of badger burrows after the 1989 growing season than in nearby locations away from burrows. Studies are currently underway to determine whether the preferential drying occurs in soils beneath the burrows in the absence of vegetation.

Other observations were made with the large-mammal burrows. These observations were summarized by Cadwell and others in the document edited by Wing and Gee 1990.

> The FY 1989 annual characterization of existing marked badger burrows indicated that abandoned burrows are only temporary surface features that soon fill with soil and organic debris. Many of the badger burrows also connect with small-mammal burrows. The small mammals appear to be instrumental in filling the larger burrows by casting soil into the openings. More importantly, the smaller burrows provide an opportunity for runoff that enters large burrows to drain.

From the results of the testing performed to date, the presence of small-mammal burrows does not appear to have a significant effect on the deep percolation of water through the barrier. Large mammals do appear to cause increased deep penetration of water in the fine-soil layer, but it was observed that much of this water was removed later. The current barrier design does not include design features to reduce the hazards of deep water penetration through large-mammal burrows because there has been no demonstrated need based on work conducted to date.

3.2.2.4 Burrowing Animals and the Deposition of Loose Soil Castings on the Barrier Surface. The soils excavated by burrowing animals and deposited on the surface of a protective barrier are thought to be more susceptible to accelerated erosion than the surrounding soils that have not been disturbed by animal activity. A discussion of this issue is provide below in the section pertaining to wind erosion of the barrier surface (Section 3.3.1).

3.3 WIND AND WATER EROSION CONTROL

Protective barriers are being designed to minimize the effects of wind and water erosion of the surface cover, side slopes, and toe of a protective barrier. In addition, designs for stabilizing the areas surrounding the protective barriers are being considered to minimize the deposition of wind-blown materials from these areas onto the surface of the barrier.

3.3.1 Barrier Surface

Throughout the majority of its design life, vegetation will be growing on the surface of the protective barrier. The presence of vegetation on the barrier surface will significantly reduce the amount of fine soil lost from the barrier by wind and water erosion. However, to protect the barrier surface during periods of time when the vegetative cover is disturbed by range fires, drought, disease, or some other phenomenon, surface gravels will be admixed into the surface of the protective barrier.

MITIGATING LONG TERM IMPACTS OF SMALL MAMMAL BURROWING ON THE CLOSURE OF HAZARDOUS WASTE AREAS

John W. Laundré[4]

ABSTRACT--The intrusion of burrowing mammals into hazardous waste areas (biointrusion) and the subsequent transport of waste off the burial area has been shown to be a problem on older waste areas and continues to be a concern regarding future closure of current waste areas. The objective of this study is to determine the effectiveness of three types of material (biobarriers) in preventing the burrowing of small mammals into waste areas. The three materials are 1) 5- to 10-cm (1- to 2-in.) cobble, 2) chipped roofing gravel, and 3) a mixture of gravel and cobble. Townsend's ground squirrels (*Spermophilus townsendii*) and Ord's kangaroo rat (*Dipodomys ordii*) were introduced into enclosures containing 50-cm thick layers of these materials overlaid by native soil. An additional objective was to determine if creating such a biobarrier in the presence of burrowing mammals might alter soil moisture patterns and compromise the integrity of the waste cap. After three years, there is still no evidence that the test animals have burrowed through the biobarrier layers.

Keywords: Burrowing mammals, biobarrier, landfill capping, Protective Cap/Biobarrier Experiment, soil moisture.

JUSTIFICATION

The intrusion of burrowing mammals into hazardous waste areas (biointrusion) and the subsequent transport of waste off the burial area has been shown to be a problem on older areas and continues to be a concern regarding future closure of current waste areas. Studies of burrow depths on the Idaho National Environmental and Engineering Laboratory (INEEL) have demonstrated that small mammals can potentially burrow deep enough to reach waste material within many currently closed waste areas (Reynolds and Wakkinen 1987, Laundré and Reynolds 1993). Work published by other INEEL workers has also demonstrated that small mammal burrowing has contributed to the upward transport of hazardous waste to the surface of waste areas (Arthur and Markham 1983). Consequently considerable effort is being expended on ways to mitigate the transport of waste by burrowing mammals and developing accurate risk assessments of the long term impact of small mammals on hazardous waste areas.

In FY93 a protective cap/biobarrier experiment was begun on the INEEL. The project's goal is to test the effectiveness of several possible hazardous waste disposal site covers. Incorporated into the designs to be tested are biobarriers of either gravel (EPA design) or cobble (Environmental Science and Research Foundation design). These biobarriers are designed to prevent burrowing mammals from penetrating the trench cap and act as a capillary break to limit the movement of water into the waste zone. With reference to the first property, no data are available on whether the proposed material will act as an effective biobarrier to burrowing mammals. In FY92, an effort to test the effectiveness of the proposed biobarrier material was initiated. The experimental design consists of 24 circular enclosures. Six of the enclosures function as controls; the remaining 18 contain various treatments of two barrier material as described in the methods section. Ground squirrels (*Spermophilus townsendii*) and kangaroo rats (*Dipodomys ordii*) were released into the 24 enclosures in the summer of 1992. During FY93 to FY96 the enclosures were monitored to determine if the animals have dug through the biobarrier material.

Relative to water movement, the effectiveness of abrupt soil texture changes (capillary breaks) in stopping downward

[4]Department of Biological Sciences, Idaho State University, Pocatello, ID 83209

water movement is well documented. However, it is unknown what impact burrowing mammals may have on the effectiveness of a capillary break. From 1984-92, there has been a study of the effects of small mammal burrows on soil water dynamics on the INEEL. Data collected indicate that burrows increase the amount of water that enters the soil and the depth to which it can penetrate, especially during spring recharge (Laundré 1993). If a burrow extends to or through a capillary break, increased water penetration may compromise the break's effectiveness. One of the objectives of the ongoing research is to predict the impact of mammal burrows on the water storage effectiveness of a soil profile above a capillary break. From previously collected data, regression equations have been developed that predict the extent of water infiltration from burrows. These equations should be usable to predict the impact of burrows on the water holding capacity above a capillary break. However, winter precipitation (Nov-Feb) during the study years was at or below average (<5.5 cm [2 in.] water). As of 1992, data were still lacking from the INEEL on the effects of burrows on water infiltration during spring recharge from above normal winter precipitation. Failure of a capillary break is most likely to occur at these higher precipitation amounts especially if followed by a rapid spring snow melt. Data from years of this worst case scenario of above normal precipitation and rapid snow melt are needed to validate the regression equations developed.

The enclosures used to test the different biobarriers will provide an additional test of the impact of burrows on soil storage capacity and data to help validate the regression equations developed. Each enclosure consists of 50 cm (20 in.) of the biobarrier material overlain by 50 cm (20 in.) of soil (silt/clay material used for waste disposal cover). The ground squirrels and kangaroo rats have constructed several burrows per enclosure in the soil. The enclosures are designed to catch adequate snow to provide sufficient moisture to fill the 50-cm (20 in.) layer of soil above the capillary break in the absence of burrows. The ability of the soil profiles containing burrows to hold the prescribed amount of moisture will be compared to six control enclosures identical to the biobarrier enclosures but lacking small mammals.

The results of this work will help determine the feasibility of using biobarriers to prevent small mammals from burrowing into waste areas. If the biobarriers tested prove effective, they would valuable to the Department of Energy in its hazardous waste management efforts.

Objectives

The overall objective of this project is to test the feasibility of using biobarriers to prevent small mammals from burrowing into hazardous waste areas. This objective will be accomplished by:

- Testing the effectiveness of three potential biobarrier layers to small mammal burrowing: 1) 5- to 10-cm (1- to 2-in.) cobble, 2) chipped roofing gravel, and 3) a mixture of gravel and cobble.

Two small mammal species are being used in the experiment: the kangaroo rat and Townsend's ground squirrel. These two species represent the deepest burrowing mammals on the INEEL (Reynolds and Wakkinen 1987, Laundré and Reynolds 1993). The hypothesis tested for each species is that each biobarrier layer is equally effective in preventing animals from burrowing beyond the barrier layers.

- Testing the impact of small mammal burrowing on the effectiveness of these biobarrier layers as capillary breaks to water movement into the soil.
  The hypothesis being tested is that

moisture movement beyond the capillary break during spring recharge is similar for enclosures containing small mammals and the controls.

Project Accomplishments

Project accomplishments for the calendar year 1996 include:

- Monitor burrowing activity of animals in the enclosures.
- Sampling of soil moisture above and below the biobarriers during the spring recharge.
- Initiation of excavation of burrows in enclosures

Important Results

- In the enclosures excavated, there is no evidence that either ground squirrels nor kangaroo rats have penetrated the biobarrier material.
- Soil moisture in the 50 cm (20 in.) of soil above biobarriers was significantly greater that for soil controls.

Products

Two manuscripts were submitted in calendar year 1996 and are currently under review:

- Laundré, J. W. Effect of ground squirrel burrows on plant productivity in a cool desert environment. Submitted to the Journal of Range Management.
- Laundré, J. W. The relationship between carbon isotope ratios and sagebrush productivity. Submitted to Oecologia.

A presentation, entitled *The impact of a Shallow Biobarrier on Water Recharge Patterns in a Semi-arid Environment* was developed and accepted for the 1997 International Containment Technology Conference and Exhibition to be held in St. Petersburg, Florida, February, 1997.

Literature Cited

Arthur, W. J. and O. D. Markham. 1983. Small mammal soil burrowing as a radionuclide transport vector at a radioactive waste disposal area in southeastern Idaho. Journal of Environmental Quality 12:117-122.

Laundré, J. W. 1993. Effects of small mammal burrows on water infiltration in a cool desert environment. Oecologia 94:43-48.

Laundré, J. W. and T. D. Reynolds. 1993. Effects of soil structure on burrow characteristics of five small mammal species. Great Basin Naturalist 53:358-366.

Reynolds, T. D. and W. L. Wakkinen. 1987. Characteristics of the burrows of four species of rodents in undisturbed soils in southeastern Idaho. American Midland Naturalist 118:245-250.

STUDIES ON THE EFFECTIVENESS OF BIOBARRIERS AGAINST HARVESTER ANT EXCAVATION OF BURIED WASTE: LABORATORY EXPERIMENTS

James B. Johnson and Paul E. Blom[5]

ABSTRACT--This project examined the possibility of using a layer of gravel or layers of gravel and cobble in the soil cap over buried waste as a means of preventing ant penetration into the waste. The focus of the study was on *Pogonomyrmex salinus*, the dominant harvester ant on the Idaho National Engineering and Environmental Laboratory (INEEL) site. The tests were conducted in the laboratory in "ant farms" consisting of 20.3-cm (8-in) diameter PVC tube to contain soil and an arena for ant foraging. Layers consisting of 1.8 to 2.7-cm (0.7 to 1.1-in) subangular gravel and 5 to 14-cm (2 to 5.5-in) diameter rock were incorporated into the soil column. Ant penetration to specific depths was detected by inclusion of strata of colored aquarium gravel at 25 cm (9.8 in) intervals. During 1996 we concluded tests with a 21-cm (8.3-in) layer of gravel and 10-30-10 cm (4-12-4 in) of gravel-cobble-gravel. The 21-cm (8.3-in) layer of gravel did not prevent ant penetration. In five of six tests the 50-cm (20-in) layer of gravel and cobble did prevent ant penetration.

JUSTIFICATION

Buried radioactive materials at the Idaho National Engineering and Environmental Laboratory (INEEL) could be exhumed due to animal activity. Among the organisms capable of moving buried waste are ants. Ants are numerous and taxonomically diverse in this area (Allred and Cole 1971; Blom and Clark, unpublished data), and harvester ants, *Pogonomyrmex salinus* Olsen, are widespread over the INEEL (Blom et al. 1991a). *Pogonomyrmex salinus* galleries can be extensive. Near vertical tunnels, ca. 5 mm (0.2 in) in diameter, have been found as deep as 1.8 m (6 ft) on the INEEL. Plate-like chambers radiate from the vertical tunnels (Lavigne 1969, Blom 1990). Ant excavation of these tunnels and chambers could bring radioactive waste to the surface. It is known that they can incorporate radioactive materials into their mounds if the colony is located on or near a site with contaminated soil (Blom 1990, Blom et al. 1991b). Ant mounds and galleries are likely to influence water infiltration (Blom et al. 1994, Blom and Johnson, unpublished data), which in turn could affect redistribution of buried radioactive materials. Thus, in designing a cap for shallow waste disposal, incorporation of a layer resistant to ant excavation would be extremely beneficial. Cline et al. (1980) found that a thick layer of cobble appeared to retard penetration of various organisms into a simulated shallow surface disposal trench. In their study, three colonies of *P. salinus* were successfully transferred to the simulated trench by moving a queen and a number of associated workers. The colonies prospered for two years at which time they were excavated to determine the depth of penetration. Only one channel of a single nest could be found reaching into the cobble material, from which it was concluded that the material was an adequate biobarrier. Two confounding factors prohibit this conclusion. Placement of the barrier may have been too deep (1.2 m) to be confident it had been challenged given the modest size of the test colonies (1,000 - 3,000 workers) and short duration (two years) of the experimental period. It is likely that depth to barrier and time of exposure to ants had been tested and not the material itself. The ants could have easily traversed the spaces formed by the cobble given adequate opportunity and biological need.

Objectives

This study was undertaken to test several candidate materials for their ability to stop

[5]Division of Entomology, University of Idaho, Moscow.

downward excavation of *P. salinus*. Ant colonies were transferred from the field to laboratory soil columns for the testing. In 1992-1993, 12 colonies were used to challenge 25-cm (9.8 in) thicknesses of a cobble, gravel, and cobble-gravel mixture against excavation. Based on results from these trials, subsequent years were used to examine increasing thicknesses of the gravel lens, ranging from 3 to 21 cm (1.2 to 8.3 in) at 3-cm (1.2-in) thickness increments. During 1995-1996 the basic 'biobarrier' design used in the field demonstration project at the INEEL was tested. In the laboratory trials, the compound layering of the field demonstration project, 10-30-10-cm (4-12-4 in) thick layers of gravel-cobble-gravel, respectively, stopped ant excavation.

PROJECT ACCOMPLISHMENTS

Twelve laboratory ant nest structures (Fig. 6) were packed with lake bed sediments collected south of the Radioactive Waste Management Area on the INEEL. An angular to subangular rock ranging from 1.8 cm to 2.7 cm was selected from stock found on the INEEL as an appropriate gravel. Rock, screened to a range from 5 to 14 cm, composed the cobble classification. From these materials three treatments were tested during 1995-1996. A 21-cm layer of gravel and the materials and layering used in the biobarrier field demonstration project on the INEEL were tested in two treatments (Fig. 7). The field barrier was constructed interbedding gravel-cobble-gravel in 10-30-10-cm thicknesses, respectively. In the laboratory this biobarrier was situated to begin either at a depth of 25 or 50 cm in the soil column. Ants were collected on the INEEL to establish the test colonies. The 12 laboratory structures were grouped into three blocks of four. During the first trial (1992-1993) ant colonies were matched to nest structure by completely random assignment. In subsequent trials the blocks were used to group colony by relative size (population) being added to the column (Table 9). Once initiated, colonies were observed for six months before the columns were dismantled for direct inspection of the soil. This permitted ample time for ant excavation to well below the treatment layer depth, and accommodated the dismantling and reconstruction of nest structures for the next trial.

IMPORTANT RESULTS

Integrity of gravel thicknesses up to 21 cm were compromised, though, once the layer thickness reached 6 cm (done in previous years), excavation below the barrier was sharply reduced. With the 21-cm gravel thickness, only one colony exhumed tracer from one depth below the barrier. Post-trial inspection of the soil indicated that two of the three colonies had excavated down to 100 cm (39.4 in). Again, though the barrier layer was breached, it was only with single tunnels and limited sub-barrier excavation occurred. Materials and configuration used in the field demonstration project appeared to be more successful in blocking ant excavation. None of the colonies exhumed tracer from below this 50-cm (19.7-in) thick layer (Fig. 8), and, upon dismantling, only one of the six colonies was found with workers penetrating into the upper reaches of the barrier (see similar observation by Cline et al. 1980). Though this biobarrier included a central, 30-cm (12-in) layer of cobble, which alone would not be expected to deter the ants (Fig. 9), the absolute thickness of the biobarrier and its structure including a 10-cm (4-in) layer of gravel above and below, render the results plausible. From the perspective of ant control, the overall integrity of this barrier design might be enhanced by the thickening of the upper gravel layer. It may be expected that the 10-30-10 cm (4-12-4 in) configuration will perform as well under field conditions. As long as the ants are able to reach depths needed for thermal and moisture regulation

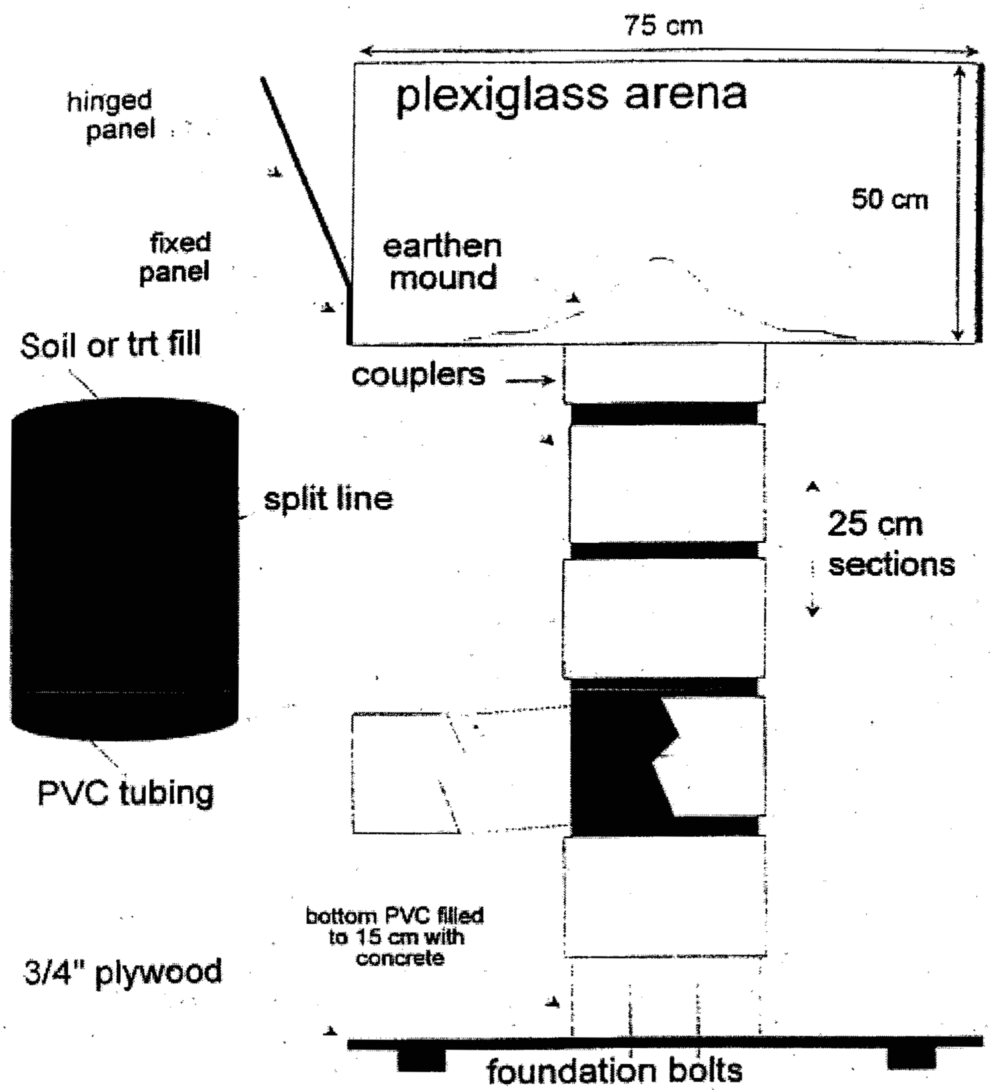


Fig. 6. Schematic of the nest structure used in laboratory testing of potential biobarriers for the exclusion of *Pogonomyrmex salinus* during nest excavation.

the unrestrained lateral geometry of the field soil profile could allow for the simple volume requirements of a large colony and not provide incentive for challenging the underlying barrier. Hence, one would reason that a deeper placement (over more shallow options) in the field situation would be preferable.

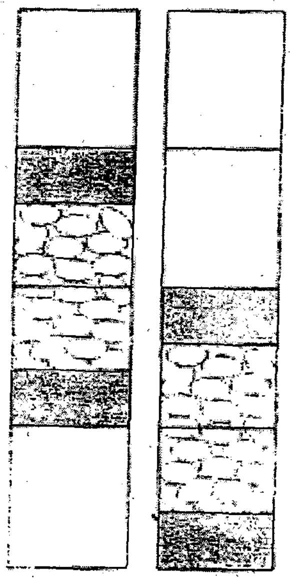


Fig. 7. Treatment configurations used in laboratory ant nest structures in 1996. Stippling indicates gravel and elliptical shapes cobble. Blank areas were filled with soil. Each section was 25 cm deep.

Literature Cited

Allred, D. M. and A. C. Cole, Jr. 1971. Ants of the National Reactor Testing Station. Great Basin Naturalist 31:237-242.

Blom, P. E. 1990. Potential impacts on radioactive waste disposal situations by the harvester ant, *Pogonomyrmex salinus* Olsen (Hymenoptera: Formicidae). M.S. Thesis. University of Idaho, Moscow. 241 pp.

Blom, P. E., W. H. Clark and J. B. Johnson. 1991. Colony densities of the seed harvesting ant *Pogonomyrmex salinus* (Hymenoptera: Formicidae) in seven plant communities on the Idaho National Engineering Laboratory. Journal of the Idaho Academy of Science 27:28-36

Blom, P. E., J. B. Johnson and S. K. Rope. 1991. Concentrations of ^{137}Cs and ^{60}Co in nests of the harvester ant, *Pogonomyrmex salinus*, and associated soils near nuclear reactor waste water disposal ponds. American Midland Naturalist 126:140-151.

Blom, P. E., J. B. Johnson, B. Shafii and J. Hammel. 1994. Soil water movement related to distance from three *Pogonomyrmex salinus* (Hymenoptera: Formicidae) nests in southeastern Idaho. Journal of Arid Environments 26:241-255.

Cline, J. F., K. A. Gano and L. E. Rogers. 1980. Loose rock as biobarriers in shallow land burial. Health Physics 39:497-504.

Lavigne, R. J. 1969. Bionomics and nest structure of *Pogonomyrmex occidentalis* (Hymenoptera: Formicidae). Annals of the Entomological Society of America 62:1166-1175.

Table 9. 1996 Assignment of ant colonies to columns and treatments, colony size (number of workers) collected in the field and eventual number added to the columns. Treatments: BB25 = 10-30-10-cm thicknesses of gravel-cobble-gravel placed at a depth of 25-75 cm, BB50 = 10-30-10-cm thicknesses of gravel-cobble-gravel placed at a depth of 50-100 cm.

	Treatment		
	BB25	BB50	Control
Block 1			
Nest number	11261	11260	11259
Workers collected	4376	5807	5060
Workers added	3823	3894	3763
Percent mortality	12.6	32.9	25.6
Block 2			
Nest number	11262	11247	11263
Workers collected	3991	3550	3888
Workers added	3334	3013	3093
Percent mortality	16.5	15.1	20.4
Block 3			
Nest number	11264	11250	11265
Workers collected	2604	3418	2486
Workers added	2146	2662	2111
Percent mortality	17.6	22.1	15.1

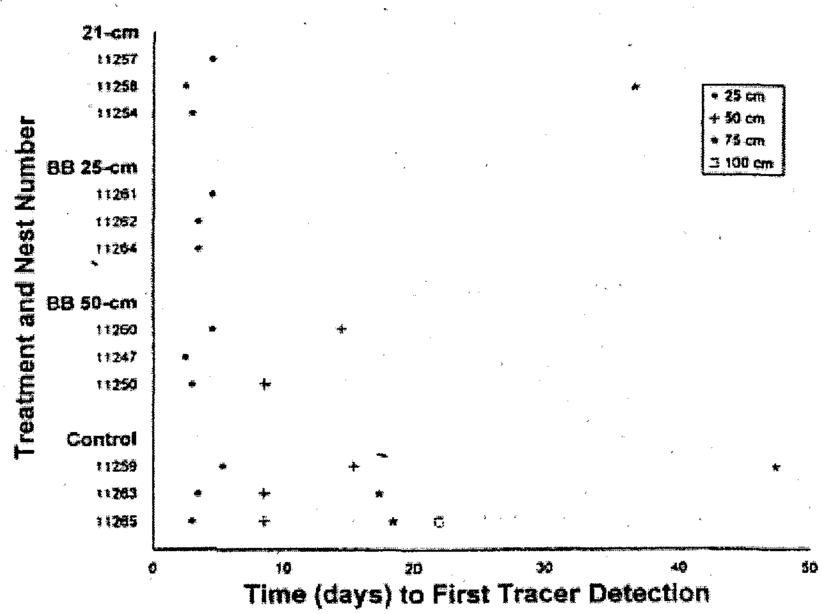


Fig. 8 1995-1996 time to exhumation of tracer gravel from 25-cm, 50-cm, 75-cm, and 100-cm depths after addition of ants to column.

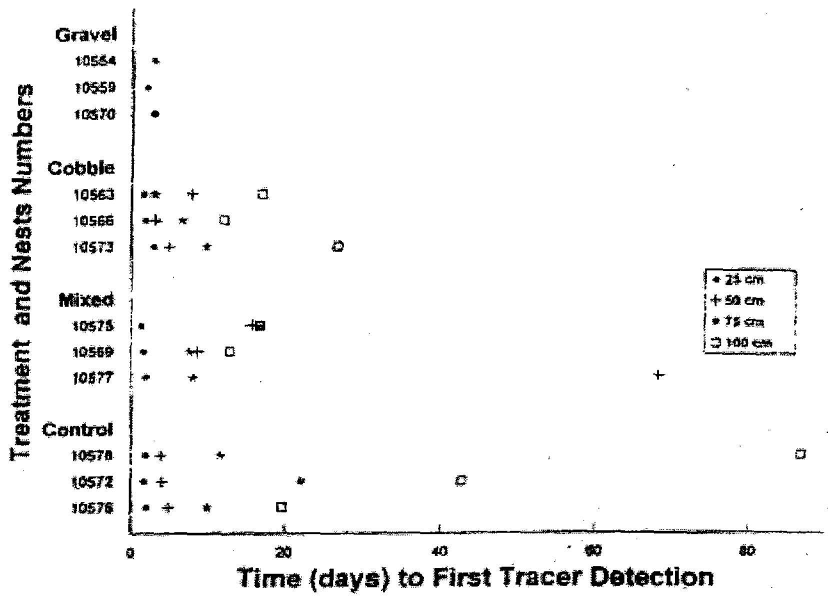


Fig. 9 1992-1993 time to exhumation of tracer gravel from 25-cm, 50-cm, 75-cm, and 100-cm depths after addition of ants to column.

STUDIES ON THE EFFECTIVENESS OF BIOBARRIERS AGAINST HARVESTER ANT EXCAVATION OF BURIED WASTE: ESTABLISHMENT OF ANT COLONIES ON THE PROTECTIVE CAP/BIOBARRIER FIELD PLOTS

Michael D. Gaglio, William P. Mackay, Erick A. Osorio, and Ivan Iniquez[4]

ABSTRACT--The harvester ant *Pogonomyrmex salinus* (Olsen) has been shown to burrow as deep as 1.8 m and excavate buried low level nuclear waste on the Idaho National Engineering and Environmental Laboratory (INEEL). As part of a larger protective cap/biobarrier experiment, we established 15 *P. salinus* nests to experimental biobarrier and control plots. Excavations and establishment took place during late July and August of 1996. Colonies were carefully established with 2000 workers and a queen. Seven colonies were active through late September, and at least six out of the 12 in experimental plots had burrowed to the top of the biobarrier layer. Monitoring of nests will continue in the spring when the colonies become active again. More nests and time are needed to thoroughly test the biobarrier and determine the effects ants may have on the protective cap/biobarrier.

Keywords: Biobarrier, harvester ant, low level nuclear waste, protective cap/biobarrier experiment.

JUSTIFICATION

The harvester ant, *Pogonomyrmex salinus* (Olsen) is distributed over the entire 2305 km^2 (890 mi^2) area of the Idaho National Engineering and Environmental Laboratory (INEEL) (Blom et al. 1991). Colony densities on the INEEL are around 20 ha^{-1} (8 $acre^{-1}$) but range from 0 to 164 ha^{-1} (0 to 66 $acre^{-1}$) (Blom et al. 1991). Nests of *P. salinus* have been shown to burrow up to 1.8 m (6 ft) deep on the INEEL (Blom 1990). Overwintering workers of *P. occidentalis* in Wyoming were found at a depth of 2.7 m (8.9 ft) by Lavigne (1969). In Washington, Fitzner et al. (1979) noted chambers in nests of *P. salinus* (as *P. owyheei*) to be 2.7 m (8.9 ft) deep in disposal soils on the Hanford nuclear reservation. Nests of *P. rugosus* and *P. subnitidus* in southern California were found by Mackay (1981) to reach depths greater than 3 m (9.9 ft) and one such nest of *P. rugosus* extended to 4 m (13.2 ft). Because *Pogonomyrmex* is such an invasive creature, they create special problems for nuclear waste management on site at the INEEL. In 1990, for example, Blom showed that ant activity resulted in the exhumation of contaminated soils buried on the INEEL.

For these reasons, it is necessary to include nests of *P. salinus* in the experimental design of the protective cap/biobarrier project.

Objectives

The focus of this project was to:

- Establish 15 *P. salinus* colonies, each with a queen and 2000 workers, on three replicates of two versions of experimental biobarrier plots and control plots (Fig. 10).
- Determine if the ants would penetrate the gravel-cobble-gravel (10-30-10 cm thick, respectively) biobarrier placed in the three replicates for barriers at 0.5 m and 1.0 m depths.

PROJECT ACCOMPLISHMENTS

From 19 July through 17 August, 1996 we excavated 25 complete *P. salinus* nests. Mound and clearing dimensions, ant population, soil temperature, and burrow depth were recorded for each nest. Ants, seeds, larvae and other organisms inhabiting the nests were collected with a garden trowel, put into small plastic containers and separated. Of the 25 excavated nests, the queen was successfully collected in 15. To

[4]Laboratory for Environmental Biology, University of Texas at El Paso, El Paso, TX 79968

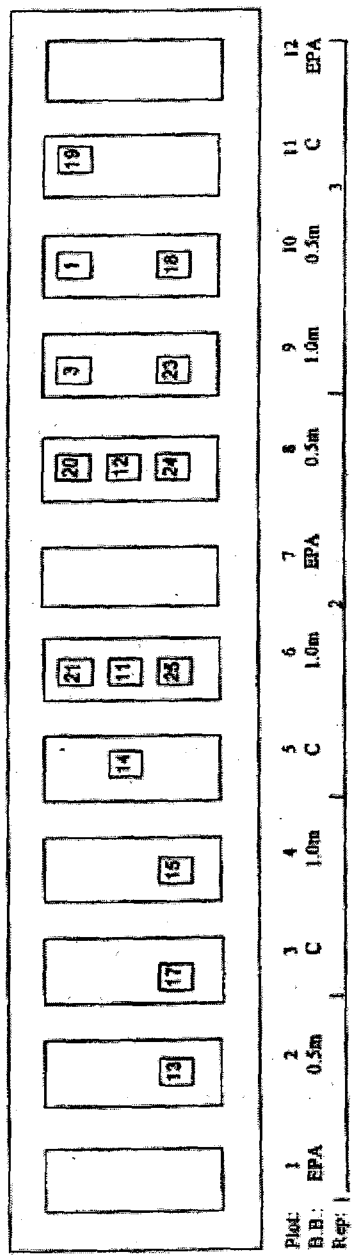


Fig. 10. Location of transplanted harvester ant nests on the Protective Cap/Biobarrier Experiment.

determine the mean mass of 100 ants, four replicates of 100 workers were weighed after collection of the first colony. Based on these determinations, we estimated the mass of 2000 workers. Two-thousand workers were removed from each colony from which a queen was successfully collected. The 15 colonies were introduced into the experimental plots in a prescribed order of treatment priority (Fig. 10, Table 10).

Important Results

Total population of a nest at establishment was ideally 2,000 workers. Four nests had populations of less than 2,000, the lowest being 1,250 workers (Table 10).

From a total of 25 excavated nests, we successfully transplanted 15 queens with their respective colonies to the experimental biobarrier and control plots, most of which had tracer materials incorporated in them. These tracers consisted of different colors of aquarium gravel which were placed in a 1-m^2 (10.9 ft^2) area above and below the biobarrier layer. Also, the tracer chemicals lithium chloride and cobalt chloride were placed at different depths in the soil of one complete cover. The occurrence of the tracer materials on the surface will help to determine burrowing depths.

Within three days, we noticed colored tracer gravel on the first nest, indicating the ants had excavated down to the top of the biobarrier at 0.5 m (1.7 ft). After that, colored gravel was seen on the surface of five more nests within one week of establishment. Two of these nests were in plots with the biobarrier at a depth of 0.5 m and the other three were in plots with the biobarrier at a depth of 1.0 m. One nest in a control plot was known to be active. A total of seven nests remained active through 24 September, 1996 (Table 11).

To determine effects on the protective cap/biobarrier as a result of ant activity, the colonies must be left undisturbed for the remaining duration of the project. More colonies may also need to be introduced to simulate the natural colony densities found on the INEEL. Once these requirements are met, we will excavate the nests to look for tracer gravel and chemicals within the nest and signs of ant activity below the biobarrier. This is necessary because ants may penetrate the biobarrier without bringing tracer gravel to the surface.

Products

This project is still in its early stages. No products were produced in 1996.

Literature Cited

Blom, P. E. 1990. Potential impacts on radioactive waste disposal situations by the harvester ant, *Pogonomyrmex salinus* Olsen (Hymenoptera: Formicidae). M.S. Thesis. University of Idaho, Moscow. 241 pp.

Blom, P. E., W. H. Clark and J. B. Johnson. 1991. Colony densities of the seed harvesting ant *Pogonomyrmex salinus* (Hymenoptera: Formicidae) in seven plant communities on the Idaho National Engineering Laboratory. Idaho Academy of Science 29:28-36.

Fitzner, R. E., K. A. Gano, W. H. Rickard and L. E. Rogers. 1979. Characterization of the Hanford 300 area burial grounds. Pages 25-27 *in* Task IV-Biological Transport. PNL-2774. Pacific Northwest Laboratory, Richland, Washington.

Lavigne, R. J. 1969. Bionomics and Nest Structure of *Pogonomyrmex occidentalis* (Hymenoptera: Formicidae). Annals of the Entomological Society of America. 62:1166-1175.

Mackay, W. P. 1981. A comparison of the nest phenologies of three species of *Pogonomyrmex* harvester ants (Hymenoptera: Formicidae). Psyche 88: 25-74.

Table 10. General nest data. See Fig. 1 for nest placement.

Nest ID	Mound dia./ Mound height (m/m)	Clear Dia. (m)	Depth (m)	Worker Popul.	Depth of Queen (m)	Temp. at Queen (°C)	Est. Popul.	Soil T (°C)
1	.85/.15	2.9	1	1500	0.6		1500	19
2	.75/.1	2.5	1.1					
3	.7/.12	1.7	1.1	5450	0.95	23	2000	
4	.7/.14	1.55	1.4	2880				
5	.9/.1	1.3						
6	.9/.15	1.4						
7	.8/.15	3.7	0.85	900	0.75	23		
8	.8/.05	3						
9	.95/.1	3	1					
10	.95/.1	3	0.6					
11	.9/.2	2.2	1.6	3310	1.3	17.6	2000	20.5
12	.5/.08	2.1	1.9	2170	1.3	18.4	2000	22
13	.5/.1	1.9	1.7	1250	1.6	18.5	1250	20.3
14	.35/.1	1	1.8	>4000	1.3	18.4	1750	23.2
15	.3/.12	1.5	1.7	1200	1.65	15.6	1200	21.8
16	.5/.16	1.45	2.3	3820				
17	.6/.12	1.4	1	>5000	0.95	19.5	2000	23
18	.8/.14	2.5	1.5	5600	1.2		2000	22.8
19	.35/.03	1.5	2.2	2644	2	14.8	2000	23.8
20	.65/.1	2.1		>5000	0.57	21.1	2000	23.5
21	.6/.12	1.9	1.4	>4000	1.1	15.7	2000	12.3
22	.4/.1	1.3	1	1000				
23	.25/.05	1.4	1.1	2500	1		2000	21.7
24	.35/.1	1.7		>5000	0.75		2000	23.2
25	.25/.05	1.6		4500	1.3	19	2000	22.5

Table 11. Afternoon colony activity of established nests in biobarrier plots as of 19 August and 24 September 1996.

Nest ID	Status 19/08/96	Status 24/08/96	Type[1]
1	>30 ants, >25 pink gravel	5 ants, >75 pink gravel	0.5
3	>20 ants, 1 pink gravel	1 ant, 4 pink gravel	1
11	>20 ants	none	1
12	>10 ants	none	0.5
13	<10 ants	none	0.5
14	>20 ants	none	C
15	none	no ants, 1 pink gravel	1
17	none	none	C
18	>10 ants	2 ants, 3 pink gravel	0.5
19	>20 ants	1 ant	C
20	>10 ants	1 ant, 1 pink gravel	0.5
21	>20 ants	none	1
23	<10 ants	none	1
24	<10 ants	none	0.5
25	>20 ants, 1 pink gravel	10 ants, 2 pink gravel	1

[1]Values in this column represent the depth in meters to the top of the 50-cm thick gravel-cobble-gravel biobarrier that is being tested. "C" is the control plot.

Appendix H

Soil Filter Layer Analysis

Cover Filter Layer Analysis

PURPOSE: Develop gradation curves for filter layers to prevent the migration of fine grained materials into coarse grained materials.

METHODOLOGY: The filter layers were designed using the guidance from the NRC published in NUREG/CR-4620. The NRC procedure is based on two criteria:

1) $$\frac{D_{15}\,(Filter\,)}{D_{85}\,(Base\,)} < 5$$

2) $$\frac{D_{15}\,(Filter\,)}{D_{85}\,(Base\,)} < 10$$

The first criteria prevents the migration finer grade materials into coarse grained layers. The second criterion is to guarantee sufficient permeability to prevent the buildup of large seepage forces and hydrostatic pressures in the filter or drain.

The filter material is the coarser of the two material. The base material is the finer of the two materials being compared. The filter layers were developed using materials already in use in the cover system. Layers were designed to prevent migration of the water storage layer soils into the riprap. The minimum layer thickness for each filter layer is half the thickness of the riprap layer but not less than 9 inches.

Calculation Objective: Determine soil gradations for the Type 1 material in the ICDF cover materials so they meet filter and piping criteria due to seepage. Fine grained soil from the Ryegrass Flats borrow area that was assumed to be placed as Engineered Earth Fill in the water storage layer.

Ryegrass Flats Area Borrow Soil

Sample #	d_{85}
#1-O	0.045
#1-O,#2	0.025
#1-P,#1	0.15
#1-P,#2	0.025
#1-Q,#1	0.035
#1-Q,#2	0.02
#3-O,#1	0.2
#3-O,#2	0.01
#3-P,Alt. #1	0.02
#3-P, Alt. 2	0.02
#3-Q,#1	0.15
#3-Q,#2	0.012
Average	0.059333
Minimum	0.01

Reference: Sherard, Embankment Dams, 1992, pp. 423 - 453.

1) **Impervious Soil Group 1 (Fine Silts and Clays):** For fine silts and clays that have more than 85% by weight of particles finer than the No. 200 sieve, the allowable filter for design should have $D_{15}<=9d_{85}$ (where d_{85} is the size of the silt or clay for which 85% is finer).

$$\frac{D_{15}\text{(of filter)}}{d_{85}\text{ (of soil)}} <= 9$$

D_{15} = ***0.09*** mm Filter material

d_{85} = ***0.01*** mm Soil material

D_{15}/d_{85} = 9 is less than or equal to 9; therefore, meets the criteria

Plot grain size curve by hand (see attached grain size distributions)

Note: A broadly graded filter has 2 advantages over a poorly graded filter: 1) it may cost less and 2) it may allow the use of a single filter band instead of a multiple band. Some existing guides limit Cu (D_{60}/D_{10}) of the filter to less than 20. The main technical reason for limiting the maximum range of filter particle size is to minimize segreation during construction. Many coarse sandy gravels with Cu near 20 are difficult to place without segregation.

Check to see if Type 1 upper limit grain size distribution meets Cu requirement of less than 20.

	D_{60} (mm)	D_{10} (mm)	Cu	
Maximum	1	0.06	16.7	Meets Cu criteria of less than 20

Draw the lower limit of the Type 1 filter material. This lower limit is subjective, but should provide a wide enough gradation so that material can be found in natural deposits or can be processed easily. This lower limit also needs to meet a Cu of less than 20.

	D_{60} (mm)	D_{10} (mm)	Cu	
Minimum	0.2	0.012	16.7	Meets Cu criteria of less than 20

Conclusion: Type 1 filter shall have gradation listed below and shown on the attached grain size curve

Sieve Size	Percent Finer
#4	100
#10	100 - 80
#20	90 - 58
#40	75 - 43
#60	65 - 33
#100	55 - 25
#200	40 - 12

Cover and Filter Layer Spreadsheet

Calculation Objective: Determine soil gradations for the Type 2 filter material in the ICDF cover materials so they meet filter and piping criteria with respect to the Type 1 filter material gradation.

Type 1 Material (see attached grain size curve)

Sample #	d_{85}
Minimum	0.7

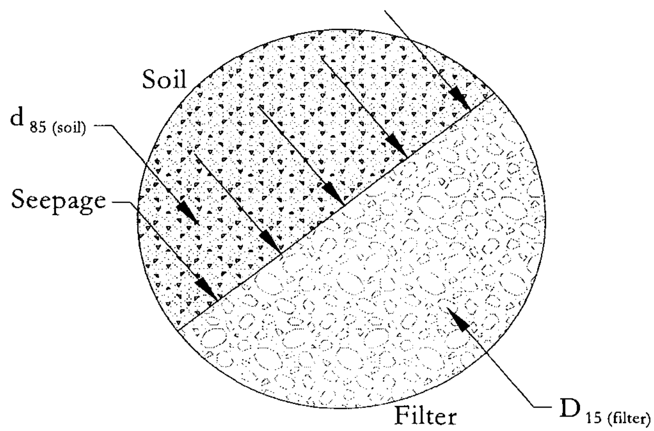
Type 1 Material (see attached grain size curve)

Sample #	d_{15}
Minimum	0.02

Calculation for minimum particle size setting the upper end of the filter criteria

Bertram (1940), with the advice of Terzaghi and Casagrande, made laboratory investigations at the Graduate School of Engineering, Harvard University, to test filter criteria suggested by Terzaghi; he established the validity of the following criteria for filter design

$$\frac{D_{15}\text{(of filter)}}{d_{85}\text{(of soil)}} < 4 \text{ to } 5 < \frac{D_{15}\text{(of filter)}}{d_{15}\text{(of soil)}}$$



D_{15} = **2** mm Filter material
d_{85} = **0.7** mm Soil material

D_{15}/d_{85} = 2.86 is less than 4; therefore, meets the criteria

Draw in the upper limit of the Type 2 grain size curve and check to see if the Cu is less than 20.

	D_{60} (mm)	D_{10} (mm)	Cu	(see attached grain size curve for Type 2 material)
Maximum	24	1.5	16.0	Meets Cu criteria of less than 20

Draw the lower limit of the Type 2 filter material. This lower limit is subjective, but should provide a wide enough gradation so that material can be found in natural deposits or can be processed easily. This lower limit also needs to meet a Cu of less than 20.

	D_{60} (mm)	D_{10} (mm)	Cu	(see attached grain size curve for Type 2 material)
Minimum	6	0.4	15.0	Meets Cu criteria of less than 20

This criterion is the piping ratio.

D_{15} = ***0.5*** mm Filter material
d_{15} = ***0.09*** mm Soil material

D_{15}/d_{15} = 5.56 is greater than 5; therefore, meets the criteria

This criterion is to guarantee sufficient permeability to prevent the buildup of large seepage forces and hydrostatic pressures in the filter or drain.

Conclusion: Type 2 filter shall have gradation listed below and shown on the attached grain size curve

Sieve Size	Percent Finer
3 in.	100
1.5 in	100 - 77
3/4 in.	86 - 57
3/8 in.	68 - 42
#4	55 - 30
#10	40 - 15
#20	23 - 0
#40	10 - 0
#60	<3

Reference: Cedergren, Seepage, Drainage, and Flow Nets, 1967, pp180-181.

Cover Filter Layer Calculation Spreadsheet

Calculation Objective: Determine soil gradations for the Type 3 (biointrusion barrier) material in the ICDF cover materials so they meet filter and piping criteria with respect to the Type 2 filter material gradation. Type 3 material also needs to meet the requirements stated in the biointrusion calculation package.

Type 2 Material (see attached grain size curve)

Sample #	d_{85}
Minimum	20

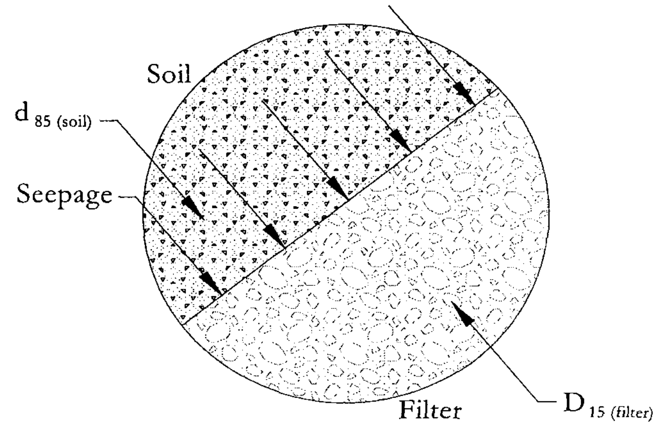
Type 2 Material (see attached grain size curve)

Sample #	d_{15}
Minimum	0.53

Calculation for minimum particle size setting the upper end of the filter criteria

Bertram (1940), with the advice of Terzaghi and Casagrande, made laboratory investigations at the Graduate School of Engineering, Harvard University, to test filter criteria suggested by Terzaghi; he established the validity of the following criteria for filter design

$$\frac{D_{15}(\text{of filter})}{d_{85}(\text{of soil})} < 4 \text{ to } 5 < \frac{D_{15}(\text{of filter})}{d_{15}(\text{of soil})}$$



D_{15} = **70** mm Filter material

d_{85} = **20** mm Soil material

D_{15}/d_{85} = 3.50 is less than 4; therefore, meets the criteria

Draw in the upper limit of the Type 3 grain size curve and check to see if the Cu is less than 20.

	D_{60} (mm)	D_{10} (mm)	Cu	
Maximum	120	70	1.7	(see attached grain size curve for Type 3 material) Meets Cu criteria of less than 20

Draw the lower limit of the Type 3 filter material. This lower limit is subjective, but should provide a wide enough gradation so that material can be found in natural deposits or can be processed easily. This lower limit also needs to meet a Cu of less than 20.

	D_{60} (mm)	D_{10} (mm)	Cu	
Minimum	65	42	1.5	(see attached grain size curve for Type 3 material) Meets Cu criteria of less than 20

This criterion is the piping ratio.

D_{15} =	**45**	mm	Filter material
d_{15} =	**2**	mm	Soil material

D_{15}/d_{15} = 22.5 is greater than 5; therefore, meets the criteria

This criterion is to guarantee sufficient permeability to prevent the buildup of large seepage forces and hydrostatic pressures in the filter or drain.

Conclusion: Type 3 material shall have gradation listed below and shown on the attached grain size curve

Sieve Size	Percent Finer
6 in.	100
3 in.	100 - 25
2 in.	30 - 0
1.5 in.	<1

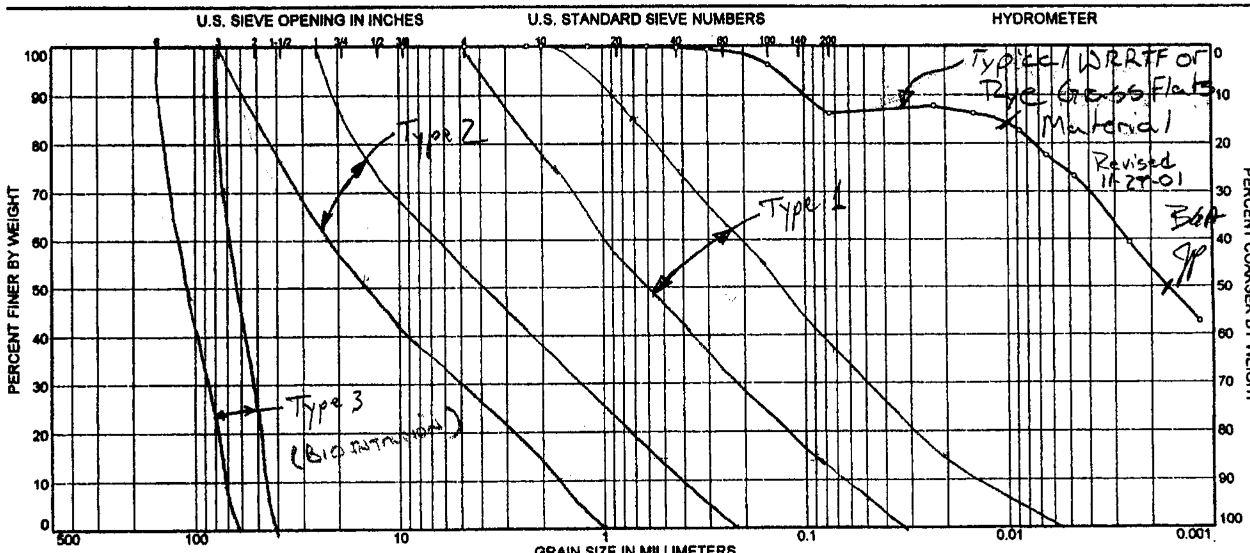
This gradation also meets the biointrusion gradation requirements

Reference: Cedergren, Seepage, Drainage, and Flow Nets, 1967, pp180-181.

Riprap Gradation Requirements
(Percent Finer by Weight)

Soil	D50 (inches)	12"	8"	6"	4"	3"	2"	1.5"	3/4"	3/8"	#4	#10	#20	#40	#60	#100	#200
Sideslope Armor	10 - 12	100	35 - 60	15 - 35	0 - 5												
Type 3 - biointrusion barrier	2.5 - 4			100	100 - 40	100 - 25	30 - 0	0 - 1									
Type 2 - coarse filter material	0.15 - 0.5					100	100 - 85	100 - 77	86 - 57	68 - 42	55 - 30	40 - 15	23 - 0	10 - 0	3 - 0		
Type 1 - fine filter material	0.005 - 0.02										100	100 - 80	90 - 58	75 - 43	65 - 33	55 - 25	40 - 12

PARTICLE SIZE DISTRIBUTION TEST REPORT



% + 3"	% GRAVEL COARSE	% GRAVEL FINE	% SAND COARSE	% SAND MEDIUM	% SAND FINE	% FINES SILT	% FINES CLAY
0.0	0.0	0.0	0.0	0.3	13.4	12.2	74.1

SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PL
WRRTF Area	#3-O #2	5.5'-6.0'	6-14-00	[illegible]	Lean clay	9.7%	39	14

Client Tom Borschel BBWI

Project INEEL CERCLA Disposal Facility (ICDF)

Project No. 3XD710130 | Plate

INEL MATERIALS LAB

o Sampled from WRRTF core #3, Borehole #3-O, core length 5.0' - 7.5'. Sampled by others.

Appendix I

Freeze-Thaw Calculation

Lining System Freeze/Thaw Evaluation – Appendix to EDF-281

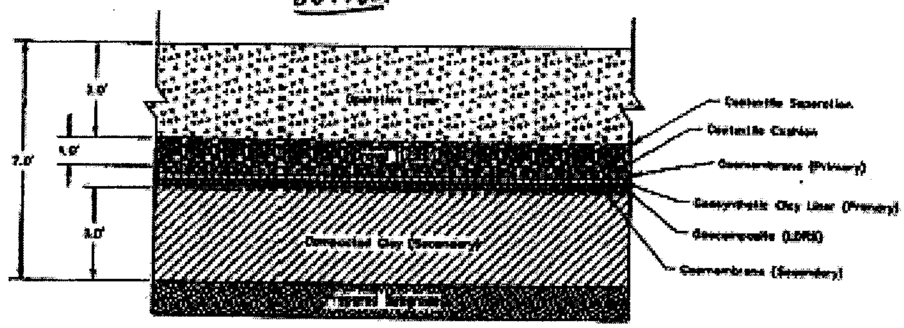
Project: ICDF Landfill and Evaporation Pond

Prepared By: M. Reimbold/CH2M HILL

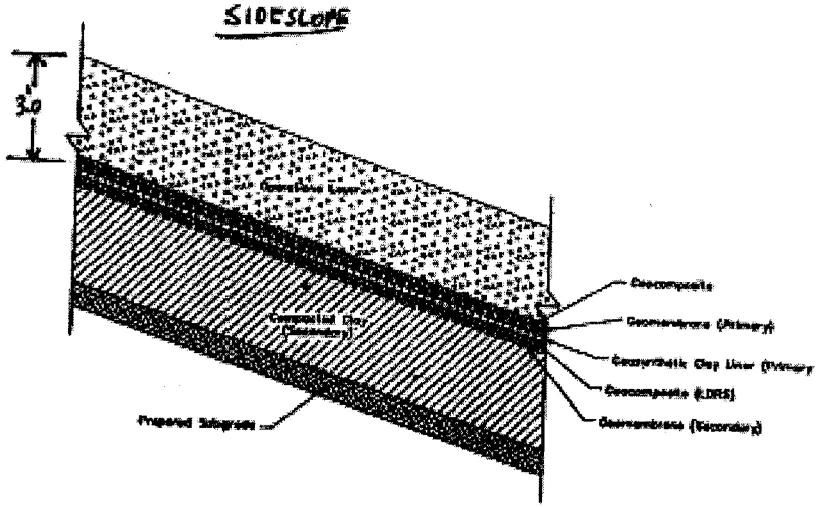
Date: 11/16/01

Given: Landfill Lining System (Bottom and Sideslope)

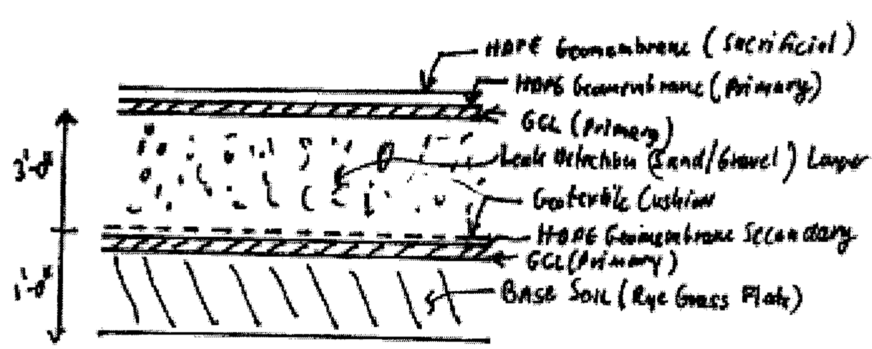
BOTTOM



SIDESLOPE



Evaporation Pond Alternative Lining System



Find: Determine depth of soil cover protection required over the GCL or CCL components of landfill and EP lining systems to provide adequate protection from freeze/thaw damage.

Approach: From Naval Facilities (NavFac) Engineering Facilities Engineering Command Design Manual 7.01 – Soil Mechanics (Sept. 1986), Figure 7, p. 7.1-42 (attached).

Provides extreme frost penetration depth (in inches) for continental U.S., based on state average.

INEEL approximate location plotted on Figure 7 results in extreme frost penetration = 45"

Landfill lining system on bottom provides 48" soil cover over the GCL and CCL

Landfill lining system on sideslope provides 36" soil cover over the GCL and CCL

EP lining system on sideslope and bottom provides 36" soil cover over the secondary GCL

Conclusion/Summary:

Proposed landfill bottom lining system provides soil cover thickness greater than extreme frost depth penetration.

Proposed landfill sideslope lining system and EP lining system provide soil cover thickness slightly less than extreme frost depth protection.

There are several mitigating factors that allow conclusion that 36"is adequate freeze/thaw protection:

- Figure from NavFac DM-7 provides extreme frost depth and it is likely that most years will have lower frost depth penetration than 45". At a minimum it can be argued that the number of freeze/thaw cycles that the GCL/CCL will be exposed to would be significantly reduced.
- Any potential insulation or protection provided by overlying geosynthetics (geomembrane, CDN, Cushion geotextile, etc) has been disregarded. While difficult to quantify these layers will provide some freeze/thaw protection.
- Recent research (Krause et al, 1997 – see EDF-312 (EP Equivalency Analysis) on GCL freeze/thaw resistance demonstrated that GCLs subject to 20 freeze/thaw cycles did not undergo hydraulic conductivity increase. With 36" soil cover protection it is likely that the GCL would be subject to no more than one freeze/thaw cycle per year. This should provide adequate protection for the GCL in the EP lining system for the 15 year design life of the facility.

Reference: NAVFAC DM 7.01 (Sept 1986)

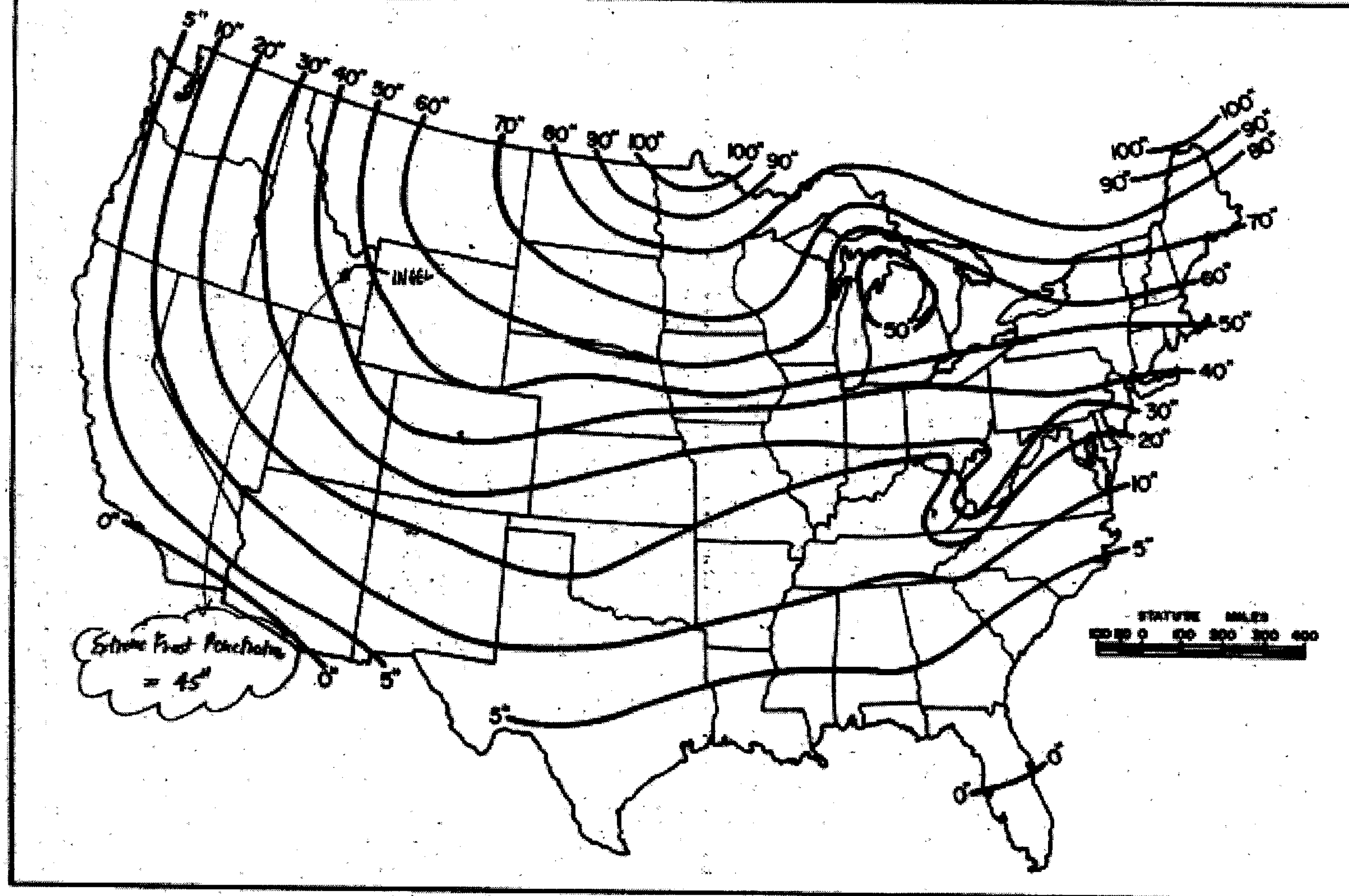


FIGURE 7
Extreme Frost Penetration (in inches) Based Upon State Average

Appendix J

Equipment Loads on Geosynthetics

ICDF - Equipment / Wheel Load on Geosynthetics SHEET NO. 1 of 3 DATE 3/12/02
PROJECT NO. 162870.28.02

Given:
Based on specification requirements, information from contractors and equipment manufacturers:

(1) Cat D6MLGP will be used for ops layer placement over geosynthetics
operating weight = 41,380#
Ground Contact Area = 8217 in²
Ground Pressure = 5.0 psi — ref: attached letter from Phenix Country and CAT info

(2) Cat D400 Haul Truck to haul ops layer over geosynthetics

use → Gross Operating Weight = 149,830# w/ full 40-Ton Rated Loaded
Ground Pressure = 25 psi @ 65 psi tire pressure and 3" penetration
ref. Phenix Const letter and CAT info

(3) Cat TH83 Telehandler (Fork Lift) will operate over Midslope Anchor Trench Berm to off-load geosynthetics

Operating Weight = 22872#
Rated Load = 8000#
30872#
Ground Pressure = 48 psi Front/Rear — ref: Barker-Wells Lift and CAT info

Find: Evaluate equipment wheel loads for planned equipment use above geosynthetics (geomembrane, GCL, CON)

a) Cushion geotextile (12 oz/sy) provides adequate protection for geomembrane @ loading = 83 psi which is significantly greater than any of above equip loading (see App B EDF-281 for these calcs)

b) CON provides required transmissivity @ 10000 psf normal load (70 psi) (see Specs section 02373) also >> loading than above equipment

c) GCL bearing capacity and potential for lateral squeezing of bentonite under equip/wheel loads needs to be evaluated.

ICDF Equipment/Wheel load on Geosynthetics — SHEET NO. 2 of 3 DATE 3/12/02
PROJECT NO. 162870.2B.02

* Bearing Capacity of GCL = same approach as for cohesive soil bearing capacity

$q_n = c N_c$ $N_c = 5.2$ (Bearing Capacity Factor for $\phi = 0$ soil)
c = cohesion (psf)

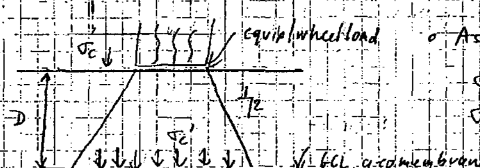
⇒ c for GCL ranges from 100 psf to > 500 psf
- 100 psf for unreinforced hydrated
- > 500 psf for reinforced, dry, prior to normal load application

- GCL for ICDF is reinforced and is between HDPE geomembrane @ ICDF and on base soil @ EP (will hydrate in ≅ 20 days) (likely dry for some time)

- Site specific internal GCL shear results in residual shear strength of $\phi = 17.9°$; $c = 400$ psf. Tests done under hydrated conditions

- Use c = 400 psf for calcs $q_{ult} = 400 \text{ psf} \times 5.2 = 2080 \text{ psf} = 14.4 \text{ psi}$

Check specific equipment loading vs. specified cover thickness, using method by Koerner and Richardson (1987), "Geosynthetic Design Guidance for Hazardous Waste Landfill Cells and Surface Impoundments".



- Assumes 2:1 stress distribution

σ_c' = contact pressure @ depth (1:1)
σ_c = ground contact pressure
R = effective radius of tire contact

$$\sigma_c' = \sigma_c \left[\frac{R^2}{(R+D)^2}\right]$$

$$R = \left[\frac{P}{\pi \sigma_c}\right]^{1/2}$$

P = Load per wheel/track

CH2M HILL ICDF- Equipment / Wheel Load on Geosynthetics SHEET NO. 3 of 5 DATE 3/12/02
PROJECT NO. 162870.2B.02

(1) Check CAT D6MLGP:

$P = 41320\#$

$\sigma_c = 5.0\,psi$

$R = \left[\frac{41.3\,kips}{\pi \times 5\,psi}\right]^{1/2} = 51.3''$

Per Specs ⇒ 1'-0" cover required min when placing granular material over geomembrane / GCL

$D = 12''$

$\sigma_c' = 5\,psi \left[\frac{(51.3'')^2}{(51.3+12)^2}\right] = 3.3\,psi$

$FS = \frac{q_{ecl}}{\sigma_c'} = \frac{14.4\,psi}{3.3\,psi} = 4.4$ OK for D6MLGP w/ 1'-0" cover

(2) Check D400 Haul Truck (Rubber Tired):

$P = 149830\#$

$\sigma_c = 25\,psi$ @ Tire Pressure = 65 psi w/ 3" penetration

12.0 psi

$R = \left[\frac{149.8\,kips}{\pi \times 25}\right]^{1/2} = 43.7''$

Per Specs ⇒ 3'-0" cover required min when operating rubber-tired vehicles on geosynthetics

$D = 36''$

$\sigma_c' = 25\,psi \left[\frac{(43.7)^2}{(43.7+36)^2}\right] = 7.5\,psi$

$FS = \frac{q_{ult}}{\sigma_c'} = \frac{14.4\,psi}{7.5}$ ⇒ 1.9 OK

given calc @ max load for haul truck

(3) Check TH83 (Rubber Tired) @ EP Midslope Anchor Trench

$P = 30872\#$

$\sigma_c = 48\,psi$

$R = \left[\frac{30872}{\pi \times 48}\right]^{1/2} = 14.3''$

⇒ Current design requires 18" cover over each layer in A.T.

$D = 18''$

$\sigma_c' = 48 \left[\frac{14.3^2}{(14.3+18)^2}\right] = 9.4\,psi$

$FS = \frac{14.4}{9.4} = 1.53$ OK for Anchor Trench Location

Conclusion: Current specs / design OK for planned equipment use.

REV 12/01 FORM 18C

Phenix of Idaho, Inc.

02/27/02

Brain Corb
CH2M HILL
1020 Landmark St.
Idaho Falls, ID 83402

Brian,

A wide pad 34" Caterpillar D6MLGP will be used to spread granular material over geomembrane. A minimum of 1 foot of granular material will be maintained between spreading equipment and geomembrane. The D6MLGP has a operating weight of 41,320 pounds and ground pressure of 4.99 PSI.

A Caterpillar D400 haul truck, or equal, will be used to import granular material. A minimum of 3 foot of granular material will be maintained between rubber-tired hauling vehicles and the geomembrane. Material will be dumped off the 3 foot fill then spread out with the D6MLGP. The D400 haul truck has a gross machine weight of 149,830 lbs. and ground pressure of 25 PSI, with tires inflated at 65 PSI and a 3" penetration.

To maintain 3 foot of material between rubber tired hauling equipment and geomembrane. 3 foot high roads will be built out of the drainage gravel material as required for placing the drainage gravel in the evaporation ponds and landfill cell. After the necessary material has been imported the 3' high roads will be spread out maintaining 1 foot of material between spreading equipment and the geomembrane.

If you have any questions, please feel free to contact me at your convenience.

Sincerely,

Lance Peterson
Phenix of Idaho, Inc.

TRACK-TYPE TRACTORS

> D6M LGP

OTHER MODELS: D6M LGP

> SPECIFICATIONS

FEATURES & BENEFITS: -- Select--

WORK TOOLS: -- Select --

Detailed Specifications

Engine	
Engine Model	3116 T
Gross Power	114 kW (153 hp)
Flywheel Power	104 kW (140 hp)
Flywheel Power - Power Shift	104 kW (140 hp)
Weights	
Operating Weight - Std.	16930 kg (37320 lb)
Operating Weight Power Shift	16500 kg (36400 lb)
Blades	
Blade Type	VPAT
VPAT Blade Width	4.08 m (13.4 ft)
Undercarriage - Std.	
Track Rollers/side	8
Track on Ground	3.08 mm (10.1 in)
Track Gauge	2.16 mm (85.2 in)
Ground Clearance	538 mm (1.75 in)
Track Width - Std.	860 mm (2.8 ft)
Ground Contact Area w/Shoe	5.3 m^2 (8217 in^2) Wt/Area = 4.54 psi
Dimensions	
Height	2.41 m (7.9 ft)

→ Use information from Phinx

Height (ROPS)	3.14 m (10.3 ft)
Length w/Blade	5.37 m (17.7 ft)
Length w/o Blade	4.15 m (13.6 ft)
Fuel Tank	
Fuel Tank Capacity	383 L (101 gal)

CAT D6MLGP

BACK TO TOP

HOME | CAT RENTAL | CAT FINANCIAL | CAT MERCHANDISE | SITEMAP | INDUSTRY SOLUTIONS | PRODUCTS | SERVICES | ABOUT CAT

- Agricultural Implements
- Backhoe Loaders
- Compactors
- Front Shovels
- Knuckleboom Loaders
- Multi Terrain Loaders
- Paving Equipment
- Scrapers
- Soil Stabilizers
- Track-Type Tractors
- Agricultural Tractors
- Cold Planers
- Forest Machines
- Harvesters
- Material Handlers
- Off Highway Tractors
- Pipelayers
- Skid Steer Loaders
- Telehandlers
- Wheel Dozers
- **Articulated Trucks**
- Combines
- Forwarders
- Hydraulic Excavators
- Motor Graders
- Off Highway Trucks
- Road Reclaimers
- Skidders
- Track Loaders
- Wheel Loaders

DEALER LOCATOR

Find a Dealer Storefront on the Web or the nearest dealer to you.

SEARCH CAT.COM

GO

RELATED LINKS

- Incident Reporting
- Get A Quote

ARTICULATED TRUCKS

HAUL TRUCK

> D400E Series II

OTHER MODELS: D400E Series II

> SPECIFICATIONS

FEATURES & BENEFITS: -- Select--

Detailed Specifications

Engine	
Engine Model	Cat 3406E
Gross Power	318 kW (427 hp)
Flywheel Power	302 kW (405 hp)
ISO 9249	302 kW (405 hp)
EEC 80/1269	302 kW (405 hp)
Bore	137 mm (5.4 in)
Stroke	165 mm (6.5 in)
Displacement	14.6 L (893 in^3)
Weights	
Rated Payload	36.3 tonnes (40 tons)
Body Capacities	
Heaped SAE 2:1	21.9 m^3 (28.6 yd^3)
Struck	16.5 m^3 (21.6 yd^3)
Heaped SAE 1:1	35.5 m^3 (27.3 yd^3)
Transmission	
Forward 1	8.76 kph (5.44 mph)
Forward 2	11.97 kph (7.44 mph)
Forward 3	16.22 kph (10.08 mph)
Forward 4	21.83 kph (13.56 mph)
Forward 5	29.58 kph (18.38 mph)

Forward 6	39.91 kph (24.81 mph)
Forward 7	58.62 kph (36.43 mph)
Reverse 1	12.44 kph (7.73 mph)
Operating Weights	
Front Axle - Empty	18150 kg (40020 lb)
Center Axle - Empty	6930 kg (15281 lb)
Rear Axle - Empty	6570 kg (14487 lb)
Total - Empty	31650 kg (69788 lb)
Front Axle - Rated Load	4480 kg (9878 lb)
Center Axle - Rated Load	15910 kg (35082 lb)
Rear Axle - Rated Load	15910 kg (35082 lb)
Total - Rated Load	36300 kg (80042 lb)
Front Axle - Loaded	22630 kg (49899 lb)
Center Axle - Loaded	22840 kg (50362 lb)
Rear Axle - Loaded	22480 kg (49568 lb)
Total - Loaded	67950 kg (149830 lb)
Body Plate Thickness	
Front	8 mm (.31 in)
Scow	16 mm (.63 in)
Side	12 mm (.47 in)
Base	16 mm (.63 in)
Service Refill Capacities	
Fuel Tank	570 L (154 gal)
Cooling System	50 L (13.5 gal)
Hydraulic System	265 L (71.5 gal)
Engine Crankcase	34 L (9.2 gal)
Transmission	55 L (14.8 gal)
Final Drives/Differential	80 L (21 gal)
Sound Levels	
Interior Cab	81 dB(A)
Body Hoist	
Raise time	12 Seconds
Lower time	7 Seconds
Standards	
Brakes	SAE J1473 OCT90 and ISO 3450-1985
Cab/FOPS	SAE J231 JAN81 and ISO 3449:1992 Level II

D400 HAUL TRUCK

↑ BACK TO TOP

THE BARBER-WEBB COMPANY

INCORPORATED

3833 EAST MEDFORD STREET • LOS ANGELES, CALIFORNIA 90063-1840
(323) 264-4800 • FAX: (323) 260-7164

NORTHWEST SALES OFFICE

1080 TIMBERLINE TERRACE, ASHLAND OREGON 97520
PHONE NUMBER: (541) 488-4821 FAX NUMBER: (541) 488-2976

****

FROM: JAMES C. BARBER DATE: 03/06/2002

NO. OF PAGES (INCLUDING COVER): 6 TIME: 10:15 A.M.

****

TO: BRIAN CORB FAX: 303-846-5404

COMPANY: CH2MHILL REF: INEEL

****

MESSAGE:

BRIAN,

ATTACHED ARE THE SPECIFICATION SHEETS FOR THE EQUIPMENT WE INTEND TO USE AT THE INEEL-CERCLA DISPOSAL FACILITY.

THE CAT TH83 TELEHANDLER, CAT IT 28G FRONT END LOADER & CAT 320 CL EXCAVATOR WILL ALL BE USED TO DEPLOY ALL PRODUCTS USED IN THE LINER SYSTEM. THEY WILL TRAVEL OVER THE COMPACTED CLAY LAYER AND THE STRUCTUAL FILL LAYER.

ADDITIONALLY THE ATV WILL BE USED TO ASSIST WITH THE PULLING OF THE LINER, DRAINAGE AND FABRIC PANELS AND WILL TRAVEL DIRECTLY ON ALL LAYERS.

THE GROUND PRESSURE (PSI) AS CALCULATED BY CATERPILLAR FOR THE HEAVY EQUIPMENT IS AS FOLLOWS.

CAT TH83-FRONT 48 PSI, REAR 48 PSI

Not on geosynthetic: CAT IT 28G-FRONT 30 PSI, REAR 25 PSI
CAT 320 CL- 48 PSI EACH TRACK

IF YOU NEED MORE INFORMATION ON THE ABOVE EQUIPMENT, OR BETTER COPY, YOU CAN VISIT THE CATAPILLAR WEBSITE @ WWW.CAT.COM. CLICK ON PRODUCTS, EQUIPMENT, NORTH AMERICA THEN WHEEL LOADER, TELEHANDLER AND HYDRAULIC EXCAVATION.

BEST REGARDS,
JAMES C. BARBER

EQUIPMENT

- Agricultural Implements
- Backhoe Loaders
- Compactors
- Front Shovels
- Knuckleboom Loaders
- Multi Terrain Loaders
- Paving Equipment
- Scrapers
- Soil Stabilizers
- Track-Type Tractors
- Agricultural Tractors
- Cold Planers
- Forest Machines
- Harvesters
- Material Handlers
- Off Highway Tractors
- Pipelayers
- Skid Steer Loaders
- **Telehandlers**
- Wheel Dozers
- Articulated Trucks
- Combines
- Forwarders
- Hydraulic Excavators
- Motor Graders
- Off Highway Trucks
- Road Reclaimers
- Skidders
- Track Loaders
- Wheel Loaders

DEALER LOCATOR

Find a Dealer Storefront on the web or the nearest dealer to you.

SEARCH CAT.COM

GO

TELEHANDLERS

Telehandler TH83

> TH83 OTHER MODELS: TH83

> SPECIFICATIONS FEATURES & BENEFITS: -- Select--

WORK TOOLS: -- Select --

RELATED LINKS

- Incident Reporting
- Get A Quote

Detailed Specifications

Operating Specifications	
Rated Load Capacity	3628 kg (8000 lb)
Max Lift Height	12.5 m (41 ft)
Top Travel Speed	32 kph (20 mph)
Load at Max Height - No Stabilizers	3175 kg (7000 lb)
Load at Max Height - Stabilizers down	3628 kg (8000 lb)
Max Foward Reach	8.2 m (27 ft)
Load at Max Reach - No Stabilizers	816 kg (1800 lb)
Load at Max Reach - Stabilizers down	1764 kg (3890 lb)
Outside Turning Radius	3.8 m (12.6 ft)
Engine	
Model	Cat 3054T
Gross Power	78 kW (105 hp)
Net Power	75 kW (101 hp)
Max. Torque	365 N.m (269 lb ft)
Bore	100 mm (3.94 in)
Stroke	127 mm (5 in)
Displacement	4 L (243 in^3)
Weights	
Operating Weight	10375 kg (22872 lb)

Telehandler TH-83

Dimensions	
Height	2490 mm (8.17 ft)
Width	2440 mm (8 ft)
Wheelbase	2975 mm (9.75 ft)
Length to Fork Face	5835 mm (19.17 ft)
Ground Clearance	495 mm (19 in)
Tires	
Basic construction pattern	14.00-24 12 PR
Basic construction pattern, high flotation	17.5-25 12PR
Hydraulic System	
Max System Pressure	250 bar (3625 psi)
Max Pump Flow	105 L/min (28 gal/min)
Max Pressure	250 bar (3625 psi)
Pump Standby Pressure	31.3 bar (455 psi)
Steering Relief Pressure	175 bar (2535 psi)
Auxiliary Hydraulic Supply	71 L/min (18.8 gal/min)
Auxiliary Hydraulic Supply	124 bar (1800 psi)
Service Refill Capacities	
Fuel Tank	117 L (31 gal)
Hydraulic Tank	136 L (36 gal)
Transmission Speeds	
Forward - 1	6 kph (4 mph)
Forward - 2	11 kph (7 mph)
Forward - 3	22 kph (14 mph)
Forward - 4	32 kph (20 mph)
Reverse - 1	6 kph (4 mph)
Reverse - 2	11 kph (7 mph)
Reverse - 3	22 kph (14 mph)

♦ BACK TO TOP

HOME | CAT RENTAL | CAT FINANCIAL | CAT MERCHANDISE | SITEMAP | INDUSTRY SOLUTIONS | PRODUCTS | SERVICES | ABOUT CAT

Appendix K

Analysis of Side Slope Riprap for the 500-year Flood Event

MWH
MONTGOMERY WATSON HARZA

By BG Adams Date 3-22-02 Client CH2M Hill Sheet 2 of 5
Chkd. By Description Check ICDF Side Slope Riprap sizing for 500 yr flood event. Job No 2470185

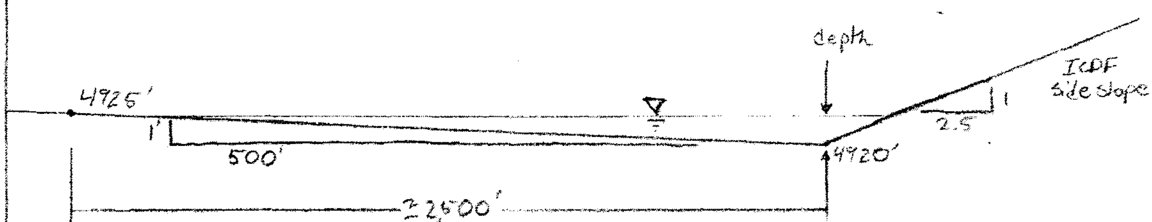
Title: Check ICDF side slope Riprap sizing for 500 yr flood event.

Method: Use Mannings equation, assuming Normal depth along the channel to estimate water height and Velocity, and the required riprap sizing for the ICDF sideslope.

Assumptions:

500 yr flood = 4,100 ft³/s
Flow overtops Big lost River above ICDF
Flow travels along the side of the ICDF
Manning Coefficient for channel = 0.035
Channel Slope = 0.24% see Topography page
Constant Slope from 4925 Contour to landfill.

Input: $Q_{500yr} = 4{,}000\ ft^3/s$
topography from USGS topography:



Calculation:

Calculation of the flood depth and velocity are shown on page C

Calculation of the Required Riprap D_{50} for V = 2.47 ft/s and d = 2.57 ft. shown on page C

Calculation of the Allowable Velocity for D_{50} = 7" and d = 2.57 ft. shown on page C

Conclusion: Using the relative D_{50} sizes the F.S. = 21.9
using the relative velocities the F.S. = 3.42
We have a factor of safety of 3.42 against scour on the ICDF landfill for a 500-yr flood event resulting in flow of 4,100 cfs.

Prepared By: Brodie Adams
Date: 3-22-02
Checked By: Micheal Ross
Date: 3-22-02

NORMAL DEPTH CALCULATION

FILE: ICDF 500-yr flood.xls
PROJECT: ICDF Title II Design
LOCATION: INEEL, Idaho

Channel Hydraulic properties (input):

Flow (cfs):	4100
Manning's n:	0.035
Bottom Width (ft):	0
Right Side Slope, z:1	2.5
Left Side Slope, z:1	500
Channel Slope (ft/ft):	0.0024

Channel Hydraulic Results:

Depth (ft) =	2.572
Hydraulic Radius (ft) =	1.286
Cross-sectional Area (ft^2) =	1662.63
Average Velocity (ft/s) =	2.47
Topwidth (ft) =	1292.65
Froude Number =	0.38
Flow condition:	SUBCRITICAL

Prepared By: Brodie Adams
Date: 3-22-02
Checked By: Micheal Ross
Date: 3-22-02

INEEL-ICDF Allowable Flood Velocity

Rip-Rap properties for input from EDF-ER-281, Appendix F

Channel Side Slope, Parallel Flows
1991 Corps of Engineers Procedure
Bed slopes less than 2 percent

FILE:	Riprap-velocity calc.xls
PROJECT:	INEEL-ICDF #2470185
LOCATION:	INEEL, Idaho
CALCULATION:	Required D_{50} for 500-yr flood event at the ICDF

Inputs:

Coefficient of Stability:	0.3 (angular rock = 0.3, rounded rock = 0.375)
Coefficient of Thickness:	1.0 (1.0 for thickness = 1*D_{100})
Safety Factor:	1.0 (PMF=1.0, otherwise 1.1)
Riprap Specific Gravity:	2.7
Angle of Side Slope (degrees):	21.8 (2.5H:1V)
Angle of Repose (degrees):	42 From EDF-ER-281, Appendix F
Coefficient of Curvature (C_v):	1.0 (1.0 for straight channels; 1.283-0.2*log(R/W) for outside of bends) (R=center-line radius of bend, W=water surface width)

Calculated Constants:

K:	0.8318
Weight Factor:	0.7670

Results:

Inputs Water Depth (ft.)	Velocity (ft/sec)	Outputs D_{30} (in)	D_{50} (in)
2.57	2.47	0.23	0.32

Prepared By: Brodie Adams
Date: 3-22-02
Checked By: Micheal Ross
Date: 3-22-02

INEEL-ICDF Allowable Flood Velocity

Rip-Rap properties for input from EDF-ER-281, Appendix F

Channel Side Slope, Parallel Flows
1991 Corps of Engineers Procedure
Bed slopes less than 2 percent

FILE:	Riprap-velocity calc.xls
PROJECT:	INEEL-ICDF #2470185
LOCATION:	INEEL, Idaho
CALCULATION:	Allowable flood velocity for 7" riprap

Inputs:

Coefficient of Stability:	0.3 (angular rock = 0.3, rounded rock = 0.375)
Coefficient of Thickness:	1.0 (1.0 for thickness = 1*D_{100})
Safety Factor:	1.0 (PMF=1.0, otherwise 1.1)
Riprap Specific Gravity:	2.7
Angle of Side Slope (degrees):	21.8 (2.5H:1V)
Angle of Repose (degrees):	42 From EDF-ER-281, Appendix F
Coefficient of Curvature (C_v):	1.0 (1.0 for straight channels; 1.283-0.2*log(R/W) for outside of bends) (R=center-line radius of bend, W=water surface width)

Calculated Constants:

K:	0.8318
Weight Factor:	0.7670

Results:

Inputs		Outputs	
Water Depth	Velocity	D_{30}	D_{50}
(ft.)	(ft/sec)	(in)	(in)
2.57	8.45	4.99	6.98